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KEITHLEY

Instruction Manual

Model 164, 164TT
Digital Multimeter

GENERAL ELECTRIC
INSTRUMENTATION & COMMUNICATION
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Keithley Instruments, Inc.
28775 Aurora Road/Cleveland, Ohio 44139/(216) 248-0400

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The measurement engineers.

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INSTRUCTION MANUAL

Digital Multimeter

Models 164, 164TT

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SPECIFICATIONS

calibrated at 25°C ± 3°C

AS A DC VOLTMETER

RANGE: ±1 microvolt per digit (1mV full range) to ±1000 volts full range in seven decade ranges. 100% overranging to 1999 on all except the 1000-volt range.
ACCURACY: ±(0.1% of reading + 1 digit) on all ranges.
INPUT RESISTANCE: 10 megohms on the 10-millivolt and higher ranges, 1 megohm on the 1-millivolt range.
AC REJECTION:
NMRR: Greater than 80 dB above on digit for a voltage of line frequency or twice line frequency on the most sensitive range, decreasing to 60 dB on the 100-millivolt and higher ranges. 1000 volts peak-to-peak maximum.
CMRR: Greater than 120 dB above one digit at dc and 40 to 100 Hz ac. 500 volts dc, 100 volts peak-to-peak ac maximum.
SETTLING TIME: Less than 2 seconds to rated accuracy.
MAXIMUM OVERLOAD: 1000 volts continuous input on 1-volt to 1000-volt ranges. 1000 volts momentary, 300 volts continuous on lower ranges.

AS A DC AMMETER

RANGE: ±0.1 nanoampere per digit (0.1μA full range) to ±1 ampere full range in eight decade ranges. 100% overranging to 1999 on all ranges.
ACCURACY: ±(0.2% of reading + 1 digit) on the 100-nanoampere to 10-milliampere ranges, ±(0.3% of reading + 1 digit) on the 0.1 and 1-ampere ranges.
INPUT RESISTANCE: 100 kilohms on the 0.1-microampere range, decreasing to 0.1 ohm on the 100-milliampere and 1-ampere ranges.
NMRR: 60 dB above one digit for a current of line frequency or twice line frequency.
MAXIMUM OVERLOAD: 50 times full scale continuous on all ranges up to a maximum of 3 amperes.

AS AN OHMMETER

RANGE: 0.1 ohm per digit (100Ω full range) to 1000 megohms full range in eight decade ranges. 100% overranging to 1999 on all ranges.
ACCURACY: ±(0.3% of reading + 1 digit + 0.1 ohm) on the 100-ohm to 1 megohm ranges, decreasing to ±10% on the 100-megohm range. The 1000-megohm range is intended for relative resistance measurements only (±50%).
VOLTAGE ACROSS UNKNOWN: 100 millivolts at full scale, 1.5 volts maximum into an open circuit.
MAXIMUM OVERLOAD: 20 volts momentary, 1 volt continuous.

AS A MILLIOHMMETER

RANGE: 10 microhms per digit (10 milliohms full range) to 200 ohms in five decade ranges. 100% overranging to 1999 on all ranges.
ACCURACY (OPERATE MODE): ±(0.3% of reading + 0.1% of range).
METHOD: 4-terminal constant current.
VOLTAGE ACROSS UNKNOWN:
VOLT-LIMIT MODE: 1 millivolt at full range, 20 millivolts open circuit.
OPERATE MODE: 1 millivolt at full range, 15 V open circuit.
MAXIMUM ALLOWABLE LEAD RESISTANCE: 20 ohms current lead resistance; 100 ohms voltage lead resistance.
MAXIMUM ALLOWABLE INPUT: 20 volts momentary, 1 volt continuous.

TRIP (164TT only)

Two trips; one high limit and one low limit on all functions.
LEVEL: —200% to + 200% of full range for each trip.
SET: ±0.1% of full range read on 3-1/2 digit display.
INDICATION: Front panel lamps.
MODE: Non-latching.
REPEATABILITY: ±0.1% of full range.
REFERENCE STABILITY: ±0.1% per °C of full range. (See GENERAL for instrument stability.)
HYSTERESIS: Less than 0.6% of full range.
RESPONSE SPEED: Negligible with respect to instrument settling time.
OUTPUT: One set of form A contacts per trip; 10 volt-amperes, 0.5 ampere, 120 volts rms ac maximum. 6 watts, 0.5 ampere, 12 volts dc maximum.
CONTROLS: Front panel push-button-lamp trip indicators; front panel trip level adjustments.
CONNECTORS: Rear panel barrier strip for trip outputs.

GENERAL

ANALOG OUTPUT: ±1 volt dc at up to 1 milliampere for full scale input, 100% overranging on all ranges except the 1000-volt range.
POLARITY: Automatic.
ZERO STABILITY: ±0.3 microvolt/°C, ±2 microvolts/day after 1-hour warm-up.
OFFSET CURRENT: Typically less than 10 picoamperes.
ACCURACY STABILITY: ±0.01%/°C (±0.06%/°C on ohms; ±0.02%/°C on milliohms). Accuracy (after a 30-minute warm-up) is maintained for at least 6 months.
DISPLAY: 3 digits plus 1 overrange digit; polarity and overload indication; 2 readings per second.
ISOLATION: Circuit ground to chassis ground: greater than 100 megohms shunted by less than 0.02 microfarad. Circuit ground may be floated up to ±500 volts with respect to chassis ground in the voltage and current modes.
POWER: 105-125 or 210-250 V (switch selected), 50-60Hz, 25 W.
DIMENSIONS, WEIGHT: 6-1/2 in. high x 9 in. wide x 10-3/4 in. deep (160 x 225 x 270 mm). Net weight, 10 pounds (4,5 kg).
ACCESSORIES SUPPLIED: Model 1641 Kelvin Test Lead Set.

SECTION 1. GENERAL INFORMATION

1-1. GENERAL.

a. DMM Mode. The Model 164 serves as a line operated 3-1/2 digit multimeter having wide ranges for measurement of voltage, current, and resistance. In the DMM mode, the 164 offers seven dc voltage ranges (from 1 microvolt per digit to 1000 volts), eight dc current ranges (from 0.1 nanoampere per digit to 2 amperes), and eight resistance ranges (from 0.1 ohm per digit to 2000 megohms).

b. Milliohmmeter-Ohmmeter Mode. The Model 164 also provides five additional resistance ranges for measurements requiring resolution to 10 microhms per digit. Four-terminal measurement technique minimizes the effects of lead and contact resistance in low-resistance measurements.

c. Electronic High/Low Limit Trip Option. The Model 164TT provides independent electronic trip circuits for high and low limits. The trips are non-latching. In addition to front panel indicator lamps, the Model 164TT offers rear panel relay contacts.

d. Digital Output Accessory. The Model 1602 is a field-installable BCD output which may be used to interface the Model 164 with a digital printer or computer.

e. AC/DC Probe Accessory. The Model 1601 AC/DC Probe permits ac voltage measurements to 250 volts rms over a span of 45 Hz to 45kHz. A probe mounted switch enables selection of ac or dc operation without disconnecting the probe.

1-2. APPLICATIONS.

The Model 164 is a general purpose instrument - used in Basic Research, Electronics Development, and Process Control.

a. In the Research Lab - When used with a suitable probe, transducer, or electronic circuit, Model 164 can be used for digital indication of volts, amps, or ohms, or through conversion, any physical parameter such as temperature, pressure, and rpm.

b. In Electronics Development Activity - Useable for basic electrical measurements of voltage, current, or resistance.

c. In Process Control Activity - Adaptable for OEM equipment where repetitive measurements are needed with analog or digital printout. Optional electronic trips permit level control capability.

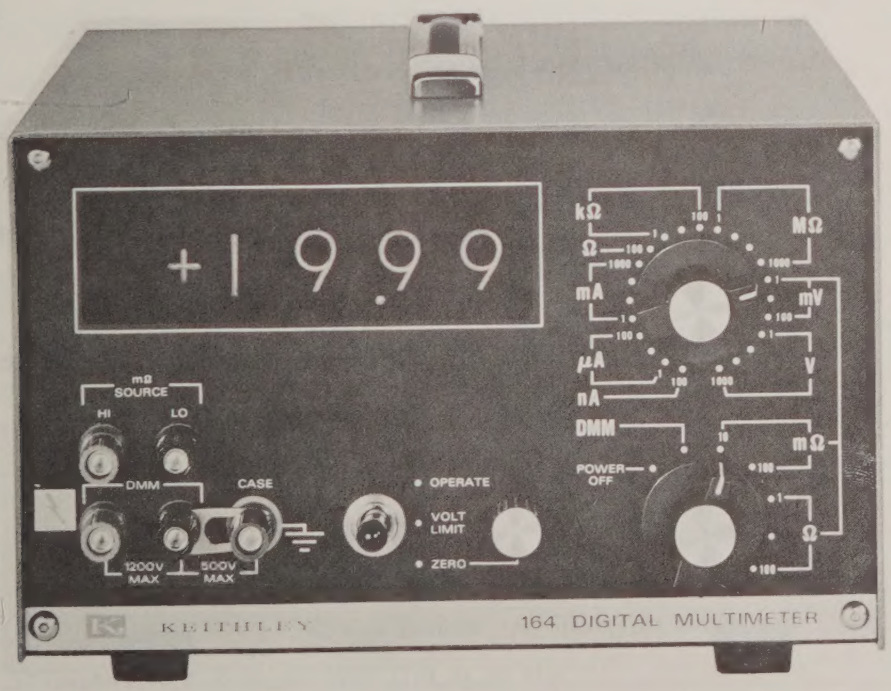


FIGURE 1. Front Panel.

TABLE 1-1.
Front Panel Controls and Terminals

Control	Functional Description	Paragraph
RANGE SWITCH	Sets the full range sensitivity and parameter to be measured (volts, amperes, or ohms in the DMM mode, or milliohms/ohms in the Milliohmmeter mode).	2-2b
mV, V	Provides seven voltage ranges from 1 millivolt full range to 1000 volts full range.	
nA, µA, mA	Provides eight current ranges from 100 nanoampere full range to 1000 milliamperes full range.	
Ω, kΩ, MΩ	Provides eight resistance ranges from 100 ohms full range to 1000 megohms full range.	
MODE SWITCH		2-2a
Power	Controls ac line power to instrument	
DMM	Sets instrument for DMM mode of operation	
mΩ,Ω	Sets instrument for any one of five resistance ranges from 10 milliohm full range to 100 ohms full range. (Milliohm current source terminals must be connected to unknown.)	
SOURCE SWITCH		2-2c
Operate	Sets instrument for normal milliohmmeter operation (non-voltage limit mode).	
Volt Limit	Sets instrument for volt-limit operation such that maximum open-circuit voltage is limited to 20 millivolts. In this mode, measurement accuracy is degraded depending on the resistance to be measured. See 2-9e.	2-9e
Zero	Sets instrument for compensating thermal emfs in the milliohmmeter mode. (Used in conjunction with the Zero control.)	
ZERO CONTROL	Permits adjustment of display zero.	2-2d
mΩ SOURCE TERMINALS		2-1a
Red	Current source high (positive polarity)	
Black	Current Source low (negative polarity)	
DMM TERMINALS		2-1a
Red	Input high	
Black	Input low	
Green	Case ground	

TABLE 1-2.
Rear Panel Controls and Terminals

Control	Functional Description	Paragraph
Line Switch (117-234V)	Sets instrument for either 117 or 234 volt line power.	2-3a
AC Power Receptacle	Mates with 3-wire ac line cord.	2-4b
Zero Control	Screwdriver adjustment for zeroing on 1 mV	2-3b
Output Receptacle	Analog Output. (± 1 volt dc at full range at up to 1 milliampere).	2-12
BCD Output Receptacle	Optional BCD output available with Model 1602 Digital Output Kit.	2-14

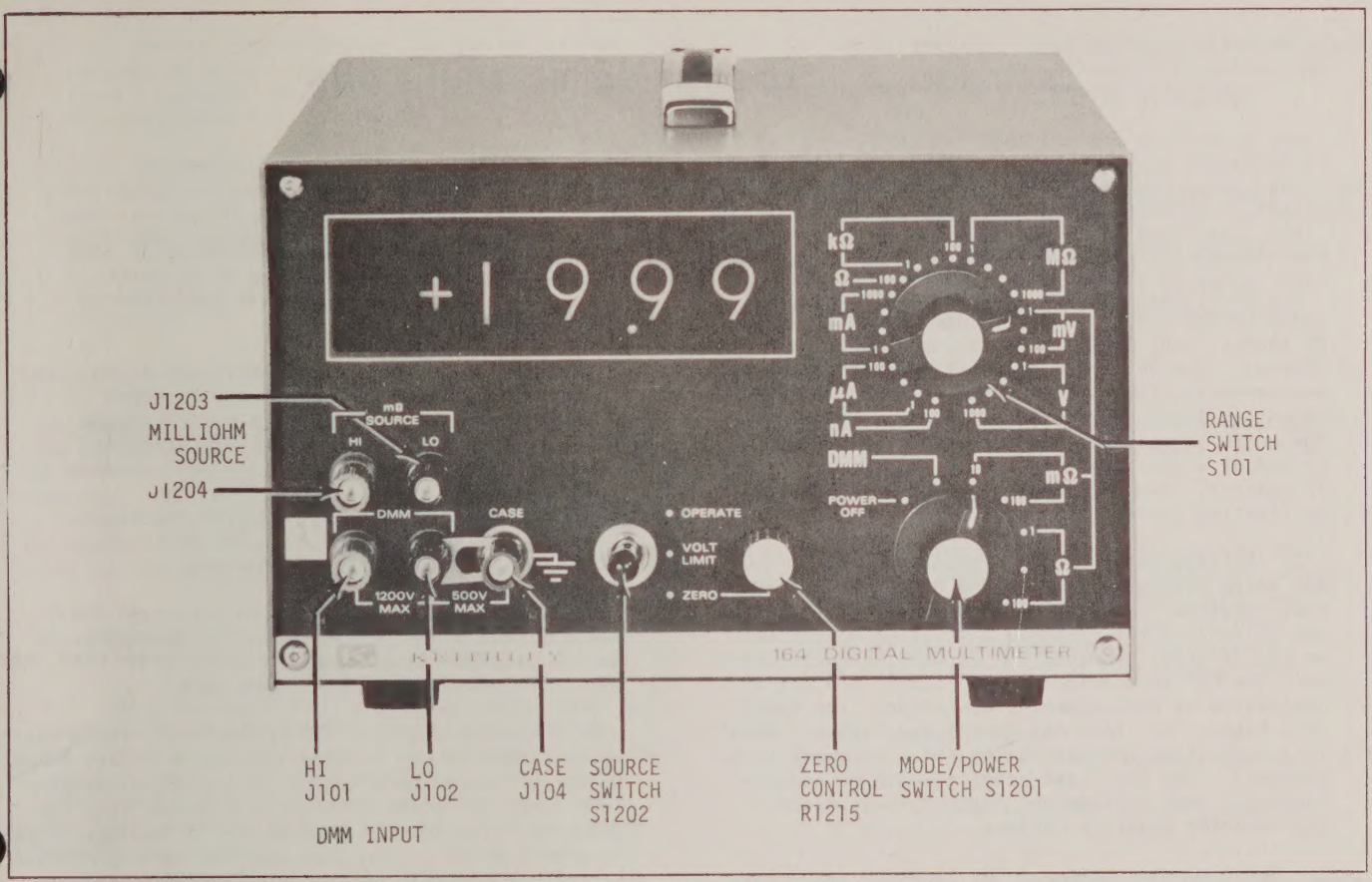


FIGURE 2. Front Panel Controls & Terminals, Model 164.

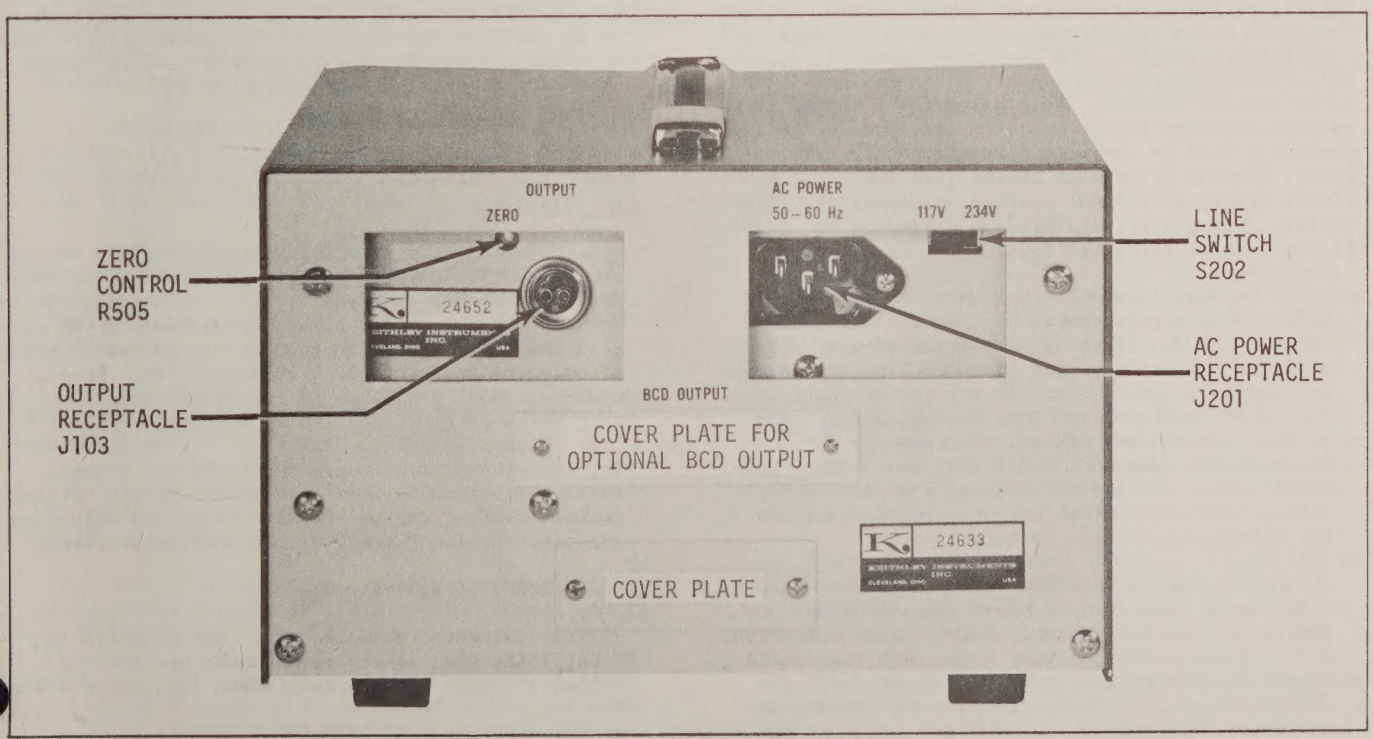


FIGURE 3. Rear Panel Controls & Terminals, Model 164.

SECTION 2. OPERATING INSTRUCTIONS

2-1. INPUT CONNECTIONS.

a. Binding Post Terminals.

1. DMM Mode. Binding post terminals are provided on the front panel for connections to input HI (Red), input LO (Black), and chassis ground (Green). For voltmeter, ammeter, and ohmmeter measurements, the source should be connected between the lower set of red and black terminals. The green terminal may be connected to input LO by use of a shorting link when grounded operation is desired. See paragraph 2-11 for a discussion of floating operation.

2. Milliohmmeter Mode. A separate pair of red and black terminals is provided for use when making four-terminal resistance measurements. The milliohm current source provides a positive dc current at the HI (Red) terminal and is used in conjunction with the DMM terminals. See paragraph 2-9 for a discussion of milliohmmeter operation. The Model 1641 Kelvin Test Lead Set (furnished with the Model 164) simplifies connections to the resistance to be measured. The Test Lead provides clip-on connections for both voltage and current leads without the need for separate cables.

b. Noise Considerations. The limit of resolution in voltage and current measurements is determined largely by the noise generated in the source. Stray low-level noise is present in some form in nearly all electrical circuits. The instrument does not distinguish between stray and signal voltages since it measures the net voltage. When using the 1 mV and 10 mV ranges, consider the presence of low-level electrical phenomena such as thermocouples (thermoelectric effect), flexing of coaxial cables (triboelectric effect), apparent residual charges on capacitors (dielectric obsorption), and battery action of two different contact materials (galvanic action).

1. Thermal EMFs. Thermal emfs (thermoelectric potentials) are generated by thermal differences between two junctions of dissimilar metals. To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the instrument. The front or rear panel ZERO control can be used to buck out thermal offsets if necessary. The Keithley accessory Model 1483 Low Thermal Connection Kit contains all necessary materials for making very low thermal copper crimp connections for minimizing thermal effects.

2. A-C Electric Fields. The presence of electric fields generated by power lines or other sources can have an effect on instrument operation. A-C voltages which are very large with respect to the full-scale range sensitivity could drive the a-c amplifier into saturation, thus producing an erroneous d-c output.

NOTE

The instrument provides attenuation of line frequency noise superimposed on an input signal. The a-c rejection is specified as follows:

NMRR: Greater than 80 dB above one digit for a voltage of line frequency or twice line frequency on the most sensitive range, decreasing to 60 dB on the 100-millivolt and higher ranges. 1000 volts peak-to-peak maximum.
CMRR: Greater than 120 dB above one digit at dc and 40 to 100 Hz ac. 500 volts dc, 100 volts peak-to-peak ac maximum

Proper shielding as described in paragraph 2-1,c can minimize noise pick-up when the instrument is in the presence of excessive a-c fields or when very sensitive measurements are being made.

3. Magnetic Fields. The presence of strong magnetic fields can be a potential source of a-c noise. Magnetic flux lines which cut a conductor can produce large a-c noise especially at power line frequencies. The voltage induced due to magnetic flux is proportional to the area enclosed by the circuit as well as the rate of change of magnetic flux. An effective way to minimize magnetic pickup is to arrange all wiring so that the loop area enclosed is as small as possible (such as twisting input leads). A second way to minimize magnetic pickup is to use shielding as described in paragraph 2-1,c.

c. Shielding.

1. Electric Fields. Shielding is usually necessary when the instrument is in the presence of very large a-c fields or when very sensitive measurements are being made. The shields of the measurement circuit and leads should be connected together to ground at only one point. This provides a "tree" configuration, which minimizes ground loops.

2. Magnetic Fields. Magnetic shielding is useful where very large magnetic fields are present. Shielding, which is available in the form of plates, foil or cables, can be used to shield the measuring circuit, the lead wires, or the instrument itself.

3. Other Considerations.

a) Voltmeter Measurements. Use shielded input leads when source resistances are greater than 1 megohm or when long input cables are used.

b) Current Measurements. On the mA current ranges, no special shielding precautions need be taken. However, on the μA and nA ranges, shielded input leads are recommended.

c) Resistance Measurements. Shielding of input leads and source are recommended for measurements on the 10 megohm through 1000 megohm ranges to prevent erroneous readings.

2-2. FRONT PANEL CONTROLS.

a. Power/Mode Switch. This switch permits selection of operating mode. The DMM position allows the Model 164 to be used as a voltmeter, ammeter, and ohmmeter. The mΩ and Ω positions allow the Model 164 to be used as a four-terminal resistance measuring instrument. The Power OFF position disconnects line power to the instrument.

b. Range Switch. This switch permits selection of function and full range in the DMM mode.

1. Dial Nomenclature. The range switch dial is marked in engineering units for voltage, current, and resistance, that is mV, V (Voltage), nA, μA, mA (Current) and Ω, kΩ, MΩ (Resistance). For each parameter, rotating the knob clockwise switches to the less sensitive range. Decimal point is automatically positioned.

2. Voltage Function. The voltage sectors of the Range Switch are designated in millivolts (mV) and volts (V) for full ranges from 1 millivolt to 1000 volts. A full stop at the 1000 volt range prevents inadvertant switching to the nanoampere ranges with clockwise switch rotation.

3. Resistance Function. The resistance (ohms) sectors of the Range Switch are designated in ohms (Ω), kilohms (KΩ), and Megohms(MΩ) for full ranges from 100 ohms to 1000 megohms.

4. Current Function. The current (amperes) sectors of the Range Switch are designated in nanoamperes (nA), microamperes (μA), and milliamperes (mA), for full ranges from 100 nanoamperes to 1000 milliamperes.

c. Source Switch. This switch permits selection of Operate, Volt Limit, or Zero operation when using the mΩ, Ω modes.

1. Operate Position. This position permits normal operation of the Model 164 as a four-terminal resistance measuring instrument.

2. Volt Limit Position. This position limits the open-circuit voltage of the milliohm current source to 20 millivolts. In this mode, measurement accuracy is degraded depending on the resistance to be measured. For example, if a full range resistance is connected (such as 1Ω on the 1Ω Range) the measurement accuracy is degraded by 5% since a 20Ω resistance is shunting the input.

3. Zero Position. This position disconnects the current source from the unknown for zeroing the Model 164 in the milliohmmeter mode only.

d. Zero Control. This control is used in conjunction with the Source Switch (Zero Position) to zero the reading in the milliohmmeter mode. The control may also be used in the DMM mode for adjustments on the 1 mV and 10 mV ranges. (A rear panel zero adjustment is also provided for making coarse zero adjustments.) Place a short across voltmeter terminals before adjusting zero in Voltmeter mode.

2-3. REAR PANEL CONTROLS.

a. Line Switch. The 117/234V Switch sets the instrument for 117 or 234V rms line power, 50-60 Hz.

NOTE

Separate fuses are used for 117 or 234 volt operation. The fuses are installed on printed circuit board PC-254 (mother board) and can be serviced by removing the top cover. The Line Switch connects the appropriate fuse into the primary of transformer T201.

Fuse Specifications
F201: 1/2 ampere, 3AG, SLO-BLO, Keithley Part No. FU-35.
F202: 1/4 ampere, 3AG, SLO-BLO, Keithley Part No. FU-33.

b. Zero Control. This control is used for coarse zero adjustments and may be used in conjunction with the front panel ZERO Control. (Adjustment is usually necessary only for extreme changes of ambient temperature.) Place a short across voltmeter terminals before adjusting zero in Voltmeter mode.

2-4. PRELIMINARY OPERATION.

a. Line Voltage Selection. Set the Line Switch for the appropriate line voltage. For line voltages from 105 to 125 volts, set the Line Switch to 117V. For line voltages from 210 to 250 volts, set the Line Switch to 234V.

b. Line Cord. Connect the line cord to a source of 50-60 Hz line power within the ranges given above. For maximum operator safety, connect the ground wire of the line cord to earth ground. This will ensure that the CASE is at ground potential.

c. Warm-up. Set the Mode Switch to either DMM or any one of the MILLIOHMMETER positions to turn the instrument on. Allow a 1/2 hour warm-up period for measurements on 1 and 10 millivolt ranges.

d. Function/Range Selection. Select the Function and Sensitivity using the RANGE switch. In MILLIOHMMETER mode, the RANGE Switch is used in conjunction with the MODE Switch as described in paragraph 2-9.

2-5. MODES OF OPERATION. The Model 164 permits measurements in either of two modes of operation, 1) Multimeter Mode (DMM) or 2) Ohmmeter-Milliohmmeter Mode (Ω, mΩ).

a. Multimeter Mode (DMM). In the DMM mode, the Model 164 permits measurement of voltage, current, and resistance (to 0.1Ω per digit) for conventional measurements. To select the DMM mode, set the Mode Switch to the DMM position. Then set the Range Switch to the appropriate function and range.

b. Ohmmeter-Milliohmmeter Mode (Ω, mΩ). In either the Ω or mΩ modes, the Model 164 permits measurement of resistance using a four-terminal voltage-current method. To select the Ω or mΩ modes, set the Mode Switch to the desired "ohms" position. Separate terminals are provided for current and voltage sensing. The Model 1641 Kelvin Test Lead Set (furnished with the Model 164) simplifies connections to the resistance to be measured. The terminals identified as "mΩ SOURCE" provide a current in five decades from 10 microamperes to 100 milliamperes, corresponding to positions on the Mode Switch identified as 100Ω, 10Ω, 1Ω, 100mΩ, or 10mΩ. The terminals normally used for DMM measurements are for voltage sensing when making four terminal resistance measurements. The Range Switch of the Model 164 must be set to the 1mV function when using the ohmmeter-milliohmmeter modes.

2-6. VOLTMETER OPERATION (DMM Mode). This mode of operation enables voltage measurements from ±1 microvolt per digit (1 millivolt full range) to ±1000 volts.

a. Range Selection. To select voltmeter operation set the Mode Switch to DMM, then set the Range Switch to the appropriate full range voltage. As a voltmeter, the Model 164 provides seven ranges as given in Table 2-1.

TABLE 2-1.
Voltmeter Operation

Range Setting	Full Range Display	Overrange Display
1 mV	1.000 mV	1.999 mV
10 mV	10.00 mV	19.99 mV
100 mV	100.0 mV	199.9 mV
1 V	1.000 V	1.999 V
10 V	10.00 V	19.99 V
100 V	100.0 V	199.9 V
1000 V	1000. V	1000. V*

*Maximum allowable input is 1000 volts continuous input on 1-volt to 1000-volt ranges. 1000 volts momentary, 300 volts continuous on lower ranges.

b. Measurement Accuracy. The voltage accuracy is ±(0.1% of reading + 1 digit) on all ranges.

c. Overload Recovery. The instrument will recover from 300-volt overloads within five seconds on the 1mV range. Up to 1000 volts peak may be applied momentarily on any range without damaging the instrument.

d. Input Resistance. The input has a resistance of 10 megohms on the 10 millivolt and higher ranges 1 megohm on the 1-millivolt range. For 10mV and higher ranges, a 1000 ohm source resistance will introduce only 0.01% error. To maintain rated accuracy on the 1mV range, the source resistance should not exceed 100 ohms.

e. Off-Ground Measurements. The instrument low terminal can be floated ±500 volts above CASE ground for voltage measurements. Refer to paragraph 2-11 for complete instructions.

f. AC Voltage Adapter Probe. The Model 1601 AC/DC Probe permits convenient a-c voltage measurements from 0.1 volt to 250 volts rms over a span of 45 Hz to 45 kHz. A probe-mounted switch provides convenient selection of a-c or d-c operation without disconnecting the probe. Therefore, the probe may be permanently attached.

2-7. AMMETER OPERATION (DMM Mode). This mode of operation enables current measurements from 0.1 nanoampere per digit (100 nanoamperes full range) to 2 amperes with 100% overranging on all ranges.

a. Range Selection. To select ammeter operation, set the Mode Switch to DMM, then set the Range Switch to the appropriate full range current. As an ammeter, the Model 164 provides eight ranges as given in Table 2-2.

b. Connections. Connect the input terminals so as to place the Multimeter in series with the current to be measured.

c. Measurement Accuracy. The current accuracy is specified as ±0.2% of reading, ±1 digit on all ranges. Since the accuracy is specified at the input terminals, the loading effects should also be considered. See Table 2-2 for values of shunt resistors.

d. Off-Ground Measurements. The Model 164 low terminal can be floated ±500 volts above CASE ground for current measurements. Refer to paragraph 2-11 for complete instructions.

2-8. OHMMETER OPERATION (DMM Mode). This mode of operation enables resistance measurements from 0.1 ohm per digit (100 ohms full range) to 2000 megohms.

a. Range Selection. To select ohmmeter operation (DMM mode), set the Mode Switch to DMM, then set the Range Switch to the appropriate full range resistance. As an ohmmeter, the Model 164 provides eight ranges as given in Table 2-3.

b. Voltage Across the Unknown. Voltage drop is 100 millivolts at full range with 1.5 V max. into an open circuit. Thus the current through the unknown is determined by dividing the 100 millivolts by the full range resistance.

c. Maximum Overload. Maximum voltage across the input terminals is 20 volts momentary and 1 volt continuous.

d. Accuracy. As shown in Table 2-4.

TABLE 2-2.
Ammeter Operation

Range Setting	Full Range Display	Overrange Display	Shunt R
100 nA	100.0 nA	199.9 nA	10^5 Ω
1 µA	1.000 µA	1.999 µA	10^4 Ω
10 µA	10.00 µA	19.99 µA	10^3 Ω
100 µA	100.0 µA	199.9 µA	10^2 Ω
1 mA	1.000 mA	1.999 mA	10 Ω
10 mA	10.00 mA	19.99 mA	1 Ω
100 mA	100.0 mA	199.9 mA	0.1 Ω
1000 mA	1000. mA	1999. mA	0.1 Ω

TABLE 2-3.
Ohmmeter Operation

Range Setting	Full Range Display	Overrange Display	Impressed Current
100 Ω	100.0 Ω	199.9 Ω	1 mA
1 kΩ	1.000 kΩ	1.999 kΩ	0.1 mA
10 kΩ	10.00 kΩ	19.99 kΩ	0.01 mA
100 kΩ	100.0 kΩ	199.9 kΩ	1 µA
1 MΩ	1.000 MΩ	1.999 MΩ	0.1 µA
10 MΩ	10.00 MΩ	19.99 MΩ	0.01 µA
100 MΩ	100.0 MΩ	199.9 MΩ	1 nA
1000 MΩ	1000. MΩ	1999. MΩ	0.1 nA

TABLE 2-4.
Ohmmeter Accuracy

Full Scale Range	Decimal Point Position	Accuracy of Reading*
100 Ω	XX.X	±0.3% ± 0.1 Ω
1 KΩ	.XXX	±0.3%
10 KΩ	X.XX	±0.3%
100 KΩ	XX.X	±0.3%
1 MΩ	.XXX	±0.3%
10 MΩ	X.XX	±0.3%
100 MΩ	XX.X	±10%
1000 MΩ	XXX.	±50%

*±1 digit on all ranges.

2-9. OHMMETER-MILLIOHMMETER OPERATION (Ω, mΩ Mode). In the Ω/mΩ modes, the Model 164 permits measurement of resistance from 10μΩ per digit to 200Ω using a four-terminal voltage-current method.

a. Summary of Operation.

1. Connect DMM and mΩ Source terminals to resistance to be measured.

2. Set RANGE to 1mV

3. Set Mode Switch to desired range: 10mΩ, 100mΩ, 1Ω, 10Ω, or 100Ω.

4. Set Source Switch to ZERO.

5. Adjust Zero Control for zero display.

6. Set Source Switch to OPERATE (except for VOLT-LIMIT operation). Refer to section 2-9e for Volt Limit Operation.

b. Connections. Separate pairs of terminals are provided for the current source and voltmeter to facilitate four-terminal resistance measurements. The terminals identified as "mΩ SOURCE" provide a current which may be selected in five decade steps from 10 microamperes to 100 milliamperes. The terminals normally used for DMM measurements (lower pair) are the voltmeter terminals.

c. Range Selection. In the mΩ/Ω mode, the current supplied at the "mΩ SOURCE" terminals (upper pair) may be selected in five decade steps from 10 microamperes to 100 milliamperes. When the Range switch is set to 1 mV sensitivity, then the five positions on the Mode switch correspond to full ranges of 10mΩ, 100mΩ, 1Ω, 10Ω, or 100Ω. Since the full range resistance is determined by the current impressed at the "mΩ SOURCE" terminals and the voltage sensitivity, the displayed reading must be interpreted by calculating Ohm's law where $R = V/I$. When using the 1 mV Range setting, no calculation is necessary since the Model 164 provides direct-reading ranges as marked on the Mode Switch. If any other voltage range is used (other than 1 mV) the resistance must be determined by calculation since all decimal points will be lighted (therefore the decimal point location will be ambiguous). The direct-reading ranges available on the Model 164 are shown in Table 2-5.

d. Current Source. The current source in the Model 164 provides a constant current which may be selected in five decade steps from 10 microamperes to 100 milliamperes. The source can provide a compliance voltage up to 2 volts (in OPERATE mode only) on all mΩ/Ω mode settings. For example, the Model 164 may be used to furnish a current of 100 milliamperes to a load resistance of 20 ohms (giving a 2 volt drop). In the "OPERATE" mode, the Model 164 has an open-circuit voltage of approximately 15 volts. In the "VOLT LIMIT" mode, the Model 164 has an open circuit voltage of 20 millivolts.

NOTE

If the resistance to be measured is polarity sensitive, then care should be taken to connect the red (positive) terminal to the unknown so that the desired polarity is obtained. (Conventional current flow is out of the red terminal and into the black terminal.)

The effect of lead and contact resistance is minimized through the use of the four-terminal voltmeter-ammeter technique. A current source provides a known current through a pair of leads connected at one set of terminals. A sensitive voltmeter measures the voltage drop across the unknown resistance by means of a pair of leads connected at a second set of terminals.

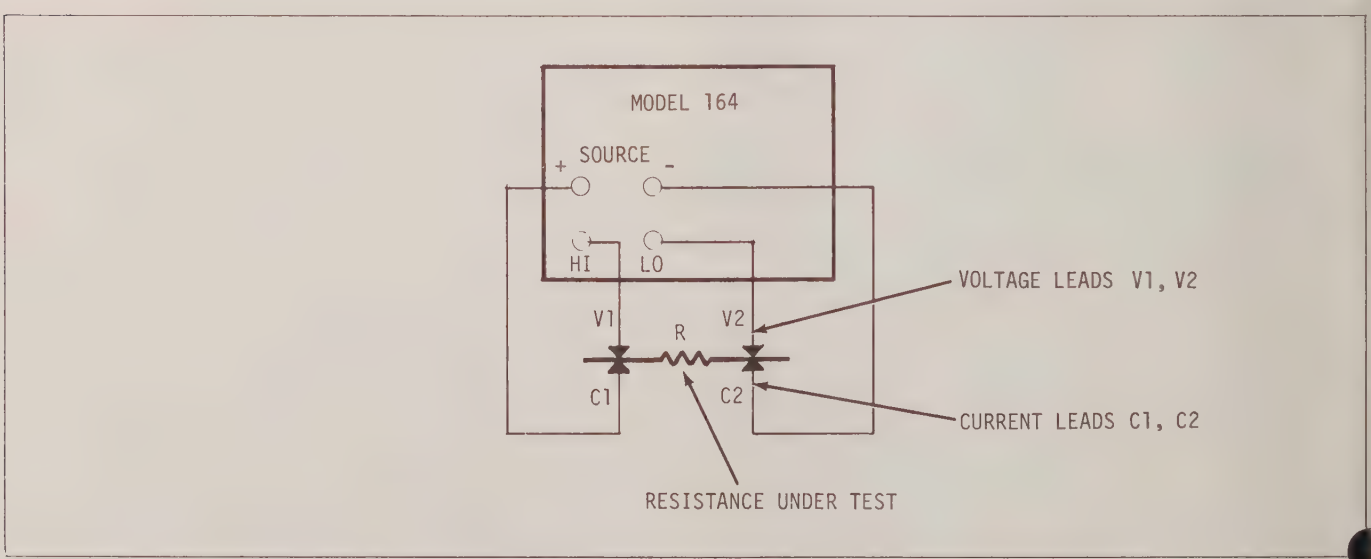


FIGURE 4. Four-Terminal Resistance Measurements

TABLE 2-5.
Full Ranges in mΩ and Ω Modes

Mode Setting	Range Setting*	Max. Reading (with 100% overranging)	mΩ Source
10 mΩ	1 mV*	19.99 mΩ	100 mA
100 mΩ	1 mV*	199.9 mΩ	10 mA
1 Ω	1 mV*	1.999 Ω	1 mA
10 Ω	1 mV*	19.99 Ω	0.1 mA
100 Ω	1 mV*	199.9 Ω	0.01 mA

*Decimal location is valid only when 1mV range is selected.

e. Voltage Limit Operation. The VOLT LIMIT mode limits the open-circuit voltage across the mΩ SOURCE terminals to 20 millivolts. This feature is useful when testing relays and switches to determine if a "dry circuit" contact is present. (For a discussion of "dry circuit" measurements, refer to ASTM Specification B539-70.)

NOTE

Measurements performed in VOLT LIMIT mode should be used for approx. readings only since a portion of the mΩ Source current is shunted through the limit resistor (R1210, 1211, 1212, 1213, or 1214) as shown on schematic 26242D.

For "dry circuit" testing, set SOURCE switch to VOLT LIMIT. If an on-scale reading is indicated, then switch to OPERATE mode and record resistance of the display. If an over-range condition is indicated then a "dry circuit" open condition is present. Since the voltage is limited to 20 mV, the 164 cannot breakdown the contact resistance unless switched to OPERATE (where up to 15 volts can be applied).

IMPORTANT!

Care should be taken to avoid a transient current pulse which may result from an overshoot of the SOURCE Switch when switching from ZERO to VOLT LIMIT positions. When making dry circuit measurements, the recommended procedure is to check the reading in VOLT LIMIT mode, then switch to ZERO to adjust for zero offsets before taking a reading in OPERATE.

f. Power Dissipation in Unknown. The power dissipated in the unknown is a function of the current impressed by the Model 164 current source. Power developed, worst-case, is dependent on the range selected and the compliance limit.

1. Volt Limit Mode. In this mode, the compliance voltage limit is set at 20 millivolts. The worst case power dissipation would be a function of V x I as shown in Table 2-6.

TABLE 2-6.
Worst Case Power Dissipation - Volt Limit Mode

Mode Setting	Volt Limit	Power Dissipation
10 mΩ	20 mV	2 milliwatts
100 mΩ	20 mV	200 microwatts
1 Ω	20 mV	20 microwatts
10 Ω	20 mV	2 microwatts
100 Ω	20 mV	0.2 microwatt

2. OPERATE Mode. In OPERATE mode, the power dissipation is a function of range selected as shown in Table 2-7.

g. Milliohmmeter Zero Adjust. Set the Source Switch to ZERO, the Mode Switch to 100Ω (or the desired range), and the Range Switch to 1 mV. Connect the unknown to the four terminals as described in paragraph 2-9a. Adjust the Milliohmmeter Zero control to give a zero reading with a flashing ± display.

CAUTION

The transient voltage which can be generated by overshoot of the SOURCE Switch could be as large as 15 volts. This voltage transient may be sufficient to explode devices such as detonators and squibs if measured in the milliohmmeter mode.

TABLE 2-7.
Power Dissipation in OPERATE Mode

Mode Setting	Power at Full Range	Power at 100% overrange
10 mΩ	100 microwatts	200 microwatts
100 mΩ	10 microwatts	20 microwatts
1 Ω	1 microwatt	2 microwatts
10 Ω	0.1 microwatt	0.2 microwatt
100 Ω	0.01 microwatt	0.02 microwatt

h. V-I Characteristic Measurements. The Model 164 provides five decade currents for use when voltage versus current measurements are required. Since the mΩ current source in the Model 164 has a compliance voltage range up to 2 volts, the Model 164 can be used for material testing or semiconductor diode checkout using the ranges given in Table 2-8.

TABLE 2-8.
V-I Characteristic Measurements

Mode Setting	Current	Range Setting	Full Range
10 mΩ	100 mA	1 mV	10 mΩ
100 mΩ	10 mA	1 mV	100 mΩ
1 Ω	1 mA	1 mV	1 Ω
10 Ω	0.1 mA	1 mV	10 Ω
100 Ω	0.01 mA	1 mV	100 Ω
10 mΩ	100 mA	10 mV*	100 mΩ*
100 mΩ	10 mA	10 mV*	1 Ω*
1 Ω	1 mA	10 mV*	10 Ω*
10 Ω	0.1 mA	10 mV*	100 Ω*
100 Ω	0.01 mA	10 mV*	1000 Ω*
10 mΩ	100 mA	100 mV*	1 Ω*
100 mΩ	10 mA	100 mV*	10 Ω*
1 Ω	1 mA	100 mV*	100 Ω*
10 Ω	0.1 mA	100 mV*	1000 Ω*
100 Ω	0.01 mA	100 mV*	10 kΩ*
10 mΩ	100 mA	1 V*	10 Ω*
100 mΩ	10 mA	1 V*	100 Ω*
1 Ω	1 mA	1 V*	1000 Ω*
10 Ω	0.1 mA	1 V*	10 kΩ*
100 Ω	0.01 mA	1 V*	100 kΩ*

*NOTE: Decimal point location is not indicated when the Range Switch is set to any position other than 1mV, since all decimal points will be lighted. However, decimal point can be determined by a sample calculation of V ÷ I for a given range.

2-10. DIGITAL DISPLAY OPERATION.

a. Voltmeter Digital Display.

1. When the Range Switch is placed in Voltage positions 1 mV through 1000V, the digital display indicates the actual voltage measured.

2. The Range Switch is designated in convenient engineering units, mV (millivolts) and V (volts) with the decimal point automatically positioned in the display.

3. The full voltage range is determined by the Range Switch.

4. An overrange display up to a maximum of 1999 is provided by an overrange "1" indicator. For an input greater than 1999, all digits will be blanked except the overrange "1" indicator. The polarity indicator will remain lighted indicating the correct polarity. To remove an overload condition, change the Range Switch to a less sensitive position or decrease the input signal magnitude.

NOTE

The maximum continuous input voltage is ±1000 volts on the 1000 volt range.

b. Ammeter Digital Display.

1. When the Range Switch is placed in Ampere positions 100 nA through 1000 mA, the Multimeter digital display indicates the voltage across a calibrated, self-contained resistor. The Range Switch automatically selects the calibrated range resistor for current measurements from 1 x 10^{-7} to 1 ampere full range.

2. The Range Switch is designated in convenient engineering units, nA (nanoamperes), μA (microamperes) and mA (milliamperes) with the decimal point automatically positioned in the display.

3. The full-scale current is determined by the Range Switch. Refer to Table 2-9 for the full-range current ranges available on the Model 164.

TABLE 2-9.
Current Display

Ampere Range	Range Switch Designation
1 x 10^{-7}	nA
1 x 10^{-6}	μA
1 x 10^{-5}	μA
1 x 10^{-4}	μA
1 x 10^{-3}	mA
1 x 10^{-2}	mA
1 x 10^{-1}	mA
1	mA

c. Ohmmeter Display.

1. When the Range Switch is placed in Ohms positions 100 Ω through 1000 MΩ, the Multimeter digital display designates the voltage across the unknown resistor with a fixed current applied.

2. The Range Switch is designated in convenient engineering units, Ω (ohms), KΩ (kilohms) and MΩ (megohms) with the decimal point automatically positioned in the readout.

3. The full-scale resistance is determined by the Range Switch. Refer to Table 2-10 for the full-range resistance ranges available on the Model 164.

TABLE 2-10.
Resistance Display

Ohms Range	Range Switch Designation
1 x 10^{2}	Ω
1 x 10^{3}	KΩ
1 x 10^{4}	KΩ
1 x 10^{5}	KΩ
1 x 10^{6}	MΩ
1 x 10^{7}	MΩ
1 x 10^{8}	MΩ
1 x 10^{9}	MΩ

2-11. FLOATING OPERATION.

a. The low terminal can be floated above CASE ground by removing the shorting link between the LO and CASE. Isolation from circuit ground to chassis ground is greater than 100 megohms shunted by less than 0.02 microfarad. Circuit ground may be floated up to ±500 volts with respect to chassis ground in the voltage and current modes.

b. When the instrument is used for off-ground voltage or current measurements, the low terminal is at floating potential. The instrument case ground should be connected to earth ground through the line and ground terminal. The shorting link between LO and CASE must be disconnected

2-12. ANALOG OUTPUT. The instrument has an analog output of ±1 volt (non-inverting) at up to 1 milliampere for recording purposes. For off-ground operation, the analog ±1 volt OUTPUT should not be connected unless an external recorder is capable of floating at ±500 volts with greater than 100 megohms isolation.

2-13. ZERO ADJUSTMENTS.

a. Short the input terminals with a low terminal connection - preferably a short copper wire or clip lead.

b. Set the front panel Range Switch to the 1 mV range.

c. Set the front panel zero control (R1215) to the full clockwise position.

d. If the digital display does not indicate +11 to +13 μV, use the rear panel ZERO Control to adjust the instrument.

e. Readjust front panel zero. Zero is indicated by flashing ± polarity lights.

f. Check for zero reading on all ranges from 10 mV to 1000 V.

NOTE

If there is an off zero reading on the 1 volt range, it will be necessary to adjust the CURRENT OFFSET ADJ. on the underside of the chassis. Refer to Figure 18.

g. Set the Range Switch to Ohms positions 1000 MΩ to 100 Ω while checking the readout so that zero is indicated on all ranges.

NOTE

If clip leads are used on the input terminals, the lead resistance may be indicated on the 100 Ω range since the last digit sensitivity is 0.1 Ω per digit.

h. Set the Range Switch to Amperes positions 1000 mA to 100 nA while checking the readout so that zero is indicated on all ranges.

i. Remove the short circuit at the input terminals.

1. Volts Ranges. The instrument will normally read off zero a small amount on the 1 mV through 100 mV ranges because of sensitivity to random noise. The readout should remain at zero on the ranges 1V through 1000V.

2. Ohms Ranges. All Ohms ranges should indicate a readout overload where all digits except a "1" in the overrange position are blanked.

3. Amperes Ranges. All current ranges should indicate a zero readout, except for noise fluctuations.

j. After the preceding checkout is made, the instrument should be useable for all measurements with no further adjustments necessary.

2-14. DIGITAL OUTPUTS AND EXTERNAL CONTROLS.

a. General.

1. The Model 1602 Digital Output Kit provides optional BCD outputs and controls.

2. Included is a 50-pin PRINTER/CONTROL Connector (receptacle) for mounting on the instrument rear panel.

3. An output buffer card plugs into a prewired connector on the chassis for either factory or user installation. Buffer card replaces PC-255 interconnecting card.

b. Output Codes and Levels.

1. The PRINTER/CONTROL Outputs are Binary Coded Decimal (BCD) Signals with 1-2-4-8 standard code.

2. The standard signal levels are as follows:

Output Logic "1" See Table 2-11 (pg. 12)

Output Logic "0" See Table 2-11 (pg. 12)

3. The Buffer Stages utilize "Open Collector" output transistors.

c. Output Information.

The Model 1602 Digital Output Kit provides various BCD outputs and controls as described in Tables 2-11 and 2-12.

TABLE 2-1[1].

Model 1602 Outputs

DIGITAL OUTPUT: BCD (1, 2, 4, 8) open collector logic (Motorola MC 858P) represents each of 3 digits, overrange digit, overload ("1"), polarity (+ = "1"), and decimal position (2 bits).

TIMING OUTPUTS:
Clock: Internal clock pulses (10 kHz count rate).
Count Interval: Logic "0" appears during count interval (i.e. pulse width is proportional to analog input signal).
Flag: Logic "1" appears for a 300 millisecond interval out of a conversion time of 500 milliseconds. No change in buffer storage is made outside this interval.

OUTPUT LOGIC LEVELS:
Output Logic "1": open transistor collector to ground with less than 100 microamperes leakage. +6 volts maximum allowable applied voltage.
Output Logic "0": transistor switch closure to ground with less than 0.5 volt saturation voltage. +35 milliamperes maximum allowable current.

REMOTE CONTROLS:
Strobe: Open circuit to ground inhibits all output lines from conducting (closure to ground enables conduction).
Hold: Closure to ground retains result of last conversion in both the output register and the display.

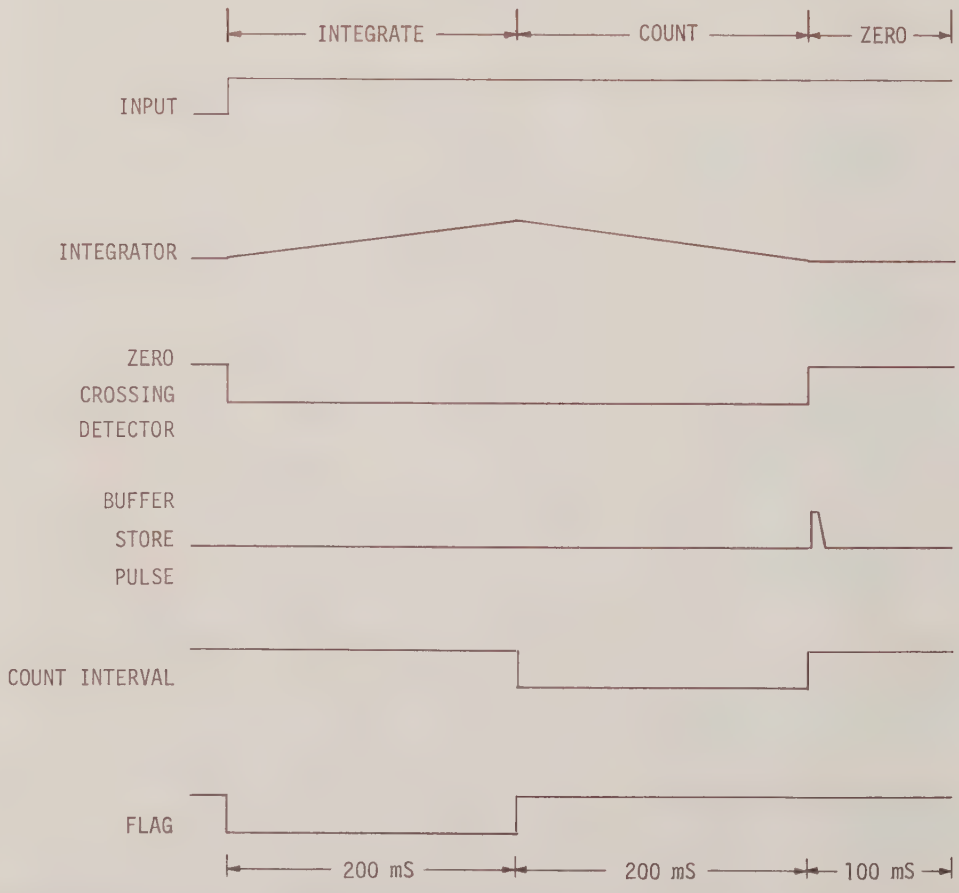


FIGURE 5. Timing Diagram for A/D Converter.

TABLE 2-12.
Model 1602 PRINTER/CONTROL Connector Pin Identification

Pin No.	Output	Function	Pin No.	Output	Function
1	1×10^0	Data	26	Common	---
2	2×10^0	Data	27	Common	---
3	4×10^0	Data	28	Blank	---
4	8×10^0	Data	29	10 kHz	Clock
5	1×10^1	Data	30	Blank	---
6	2×10^1	Data	31	Blank	---
7	4×10^1	Data	32	Blank	---
8	8×10^1	Data	33	Blank	---
9	1×10^2	Data	34	Blank	---
10	2×10^2	Data	35	Blank	---
11	4×10^2	Data	36	Blank	---
12	8×10^2	Data	37	Blank	---
13	1×10^3	Data	38	Blank	---
14	+ = Logic "1"	Polarity	39	Blank	---
15	1×10^0	Decimal Point	40	Blank	---
16	2×10^0	Decimal Point	41	Blank	---
17	Blank	---	42	Blank	---
18	Logic "1"	Overload	43	Blank	---
19	Blank	---	44	---	
20	Count Interval	See Table 2-11.	45	Blank	---
21	Blank	---	46	Blank	---
22	Blank	---	47	Hold	See Table 2-11.
23	Flag	See Table 2-11.	48	Blank	---
24	Common	---	49	Strobe	See Table 2-11.
25	Common	---	50	Blank	---

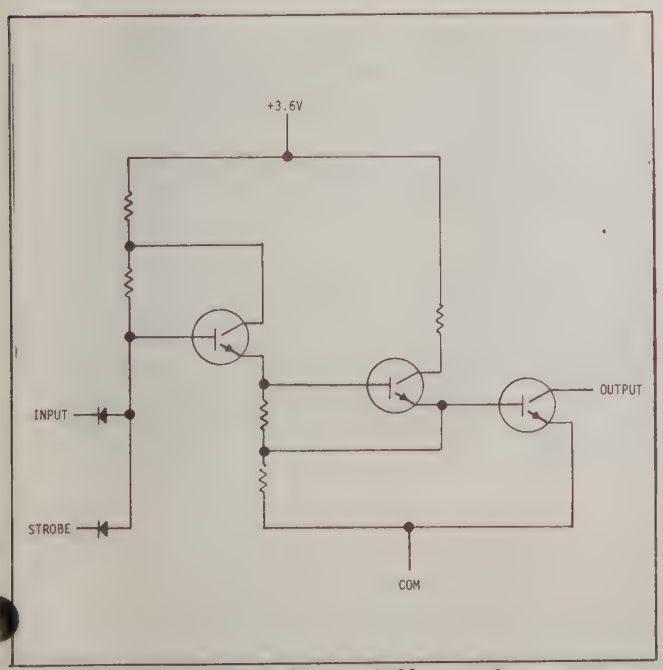


FIGURE 6. Typical Open-Collector Output.

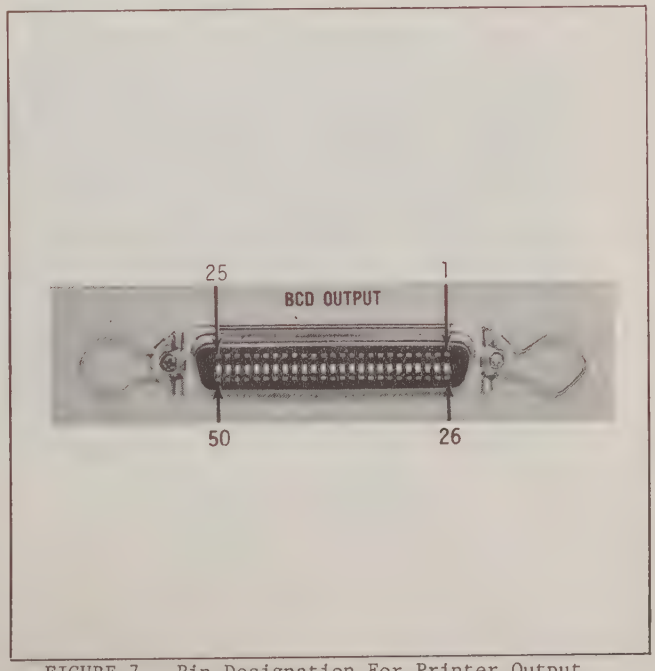


FIGURE 7. Pin Designation For Printer Output.

2-15. TRIP OPERATION (Model 164TT). The Model 164TT is identical to the standard Model 164 except for the addition of high and low limit non-latching trip circuits.

a. Trip Limits. The Model 164TT has two independently adjustable trips; one high limit and one low limit type, non-latching.

b. Trip Levels. -200% to +200% of full range for each trip. For example, if the high trip level were set to trip at a display reading of +1000, the Model 164 would indicate a "Trip" level whenever the display exceeded +1000 regardless of the function or decimal point location.

c. Trip Setting. The Model 164TT provides front panel screwdriver adjustments for the high and low trip circuits.

1. HI Trip. The front panel trip indicator lamp serves as a HI level trip indicator and a momentary contact pushbutton. When the button is depressed, the Model 164TT will display the trip reference setting. The display indicates both the polarity and reference level setting of the trip circuit. A small chisel blade screwdriver is needed to make the adjustment.

2. LO Trip. The front panel indicator lamp serves as a LO level trip indicator and a momentary contact pushbutton. When the button is depressed, the Model 164 will display the trip reference setting. The display indicates both the polarity and reference level setting of the trip circuit. A small chisel blade screwdriver is needed to make the adjustment.

3. Set Precision. The Model 164TT will indicate a trip condition when the reading is within a tolerance ±0.1% of full range with respect to the reference setting. Repeatability is ±0.1% of full range. Reference stability is ±0.1% of full range/°C.

4. Hysteresis. The trip circuit has a hysteresis of less than 0.6% of full range. For example, once the trip circuit is "tripped" the input signal must vary by at least 0.6% of full range before the trip can reset.

d. Trip Indication.

1. HI and LO Indicators. The Model 164TT provides visual indication of trip point via front panel indicator lamps.

2. Trip Contacts. One set of form A contacts are furnished for each trip. Rear panel terminals are provided.

3. Contact Ratings. 10 volt-amperes, 0.5 ampere, 120 volts rms ac maximum. 6 watts, 0.5 ampere, 12 volts dc maximum.

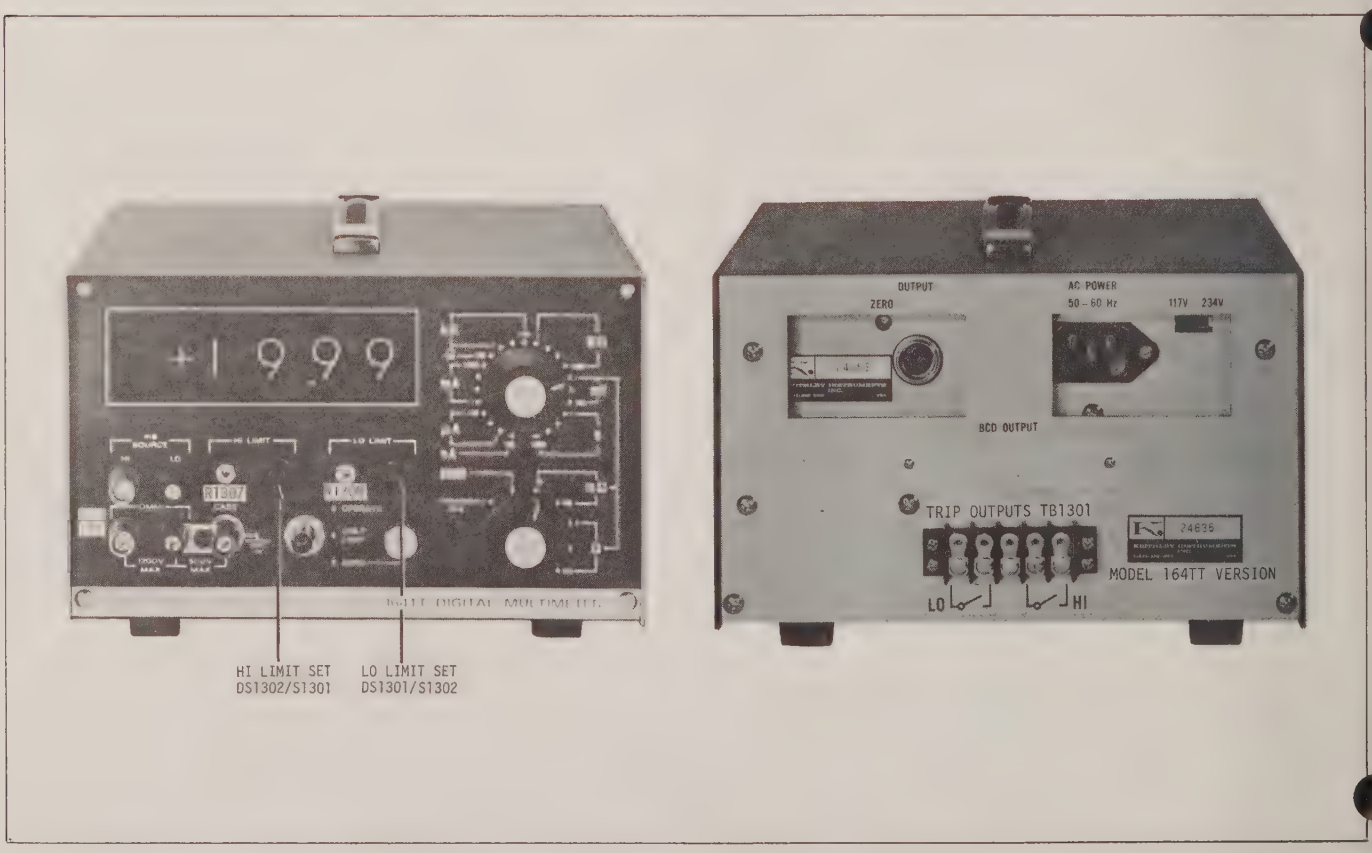


FIGURE 8. Front & Rear Panels, Model 164TT.

SECTION 3. THEORY OF OPERATION

3-1. GENERAL.

a. DMM Mode. The basic digital voltmeter consists of two sections packaged together in one chassis: 1) analog amplifier 2) analog to digital converter. The analog amplifier utilizes a modulator/demodulator technique to achieve high dc stability. The analog-to-digital converter is a dual-slope converter with two readings/second conversion rate.

b. Milliohmmeter Mode. The milliohmmeter circuitry includes a current source which provides current in decade steps from 10 microamperes to 100 milliamperes. Two additional terminals are provided on the front panel to permit four-terminal resistance measurements. The voltmeter circuitry of the basic instrument is used to monitor the voltage drop across the DMM terminals.

3-2. ANALOG AMPLIFIER OPERATION. A simplified block diagram of the analog amplifier is shown in Figure 10.

a. Voltage Amplifier Operation. The amplifier has a full-range sensitivity which is selected from 1 millivolt to 100 millivolts. Above 100 millivolts, the input signal is divided down to the 100 mV full-scale level. The signal flow path can be described as follows: An input signal applied at the Input High terminal is attenuated by a resistor divider. The signal is filtered and applied to a modulator circuit. The a-c signal is then applied and demodulated. A final variable gain d-c amplifier provides a d-c signal for the Analog output and A-to-D converter. The output is fedback to provide overall gain stability.

1. Input Resistor Divider. The input signal is attenuated by a divider network for RANGE Switch 1V, 10V, 100V and 1000V full-range positions.

2. Filter Network. The filter network provides filtering of Normal Mode noise.

3. Modulator Circuit. This circuit converts the low level d-c input to an a-c signal.

4. A-C Amplifier. This circuit uses negative feedback to provide gain accuracy and stability.

5. Demodulator Circuit. The demodulator is synchronized with the input modulator. It converts the amplified a-c signal to the d-c signal.

6. D-C Amplifier. This amplifier provides additional gain to drive the A to D converter and Analog recorder output.

7. Chopper Drive Circuit. This circuit generates the drive voltage for the mod-demod choppers.

b. Ammeter Operation (DMM Mode). The instrument operates as an ammeter by detecting the voltage drop across a known shunt resistor. The sensitivity and resistor values are shown in Table 3-1.

c. Ohmmeter Operation (DMM Mode). The instrument provides a known constant current which is applied to the unknown resistance. The voltage output is proportional to the resistance measured.

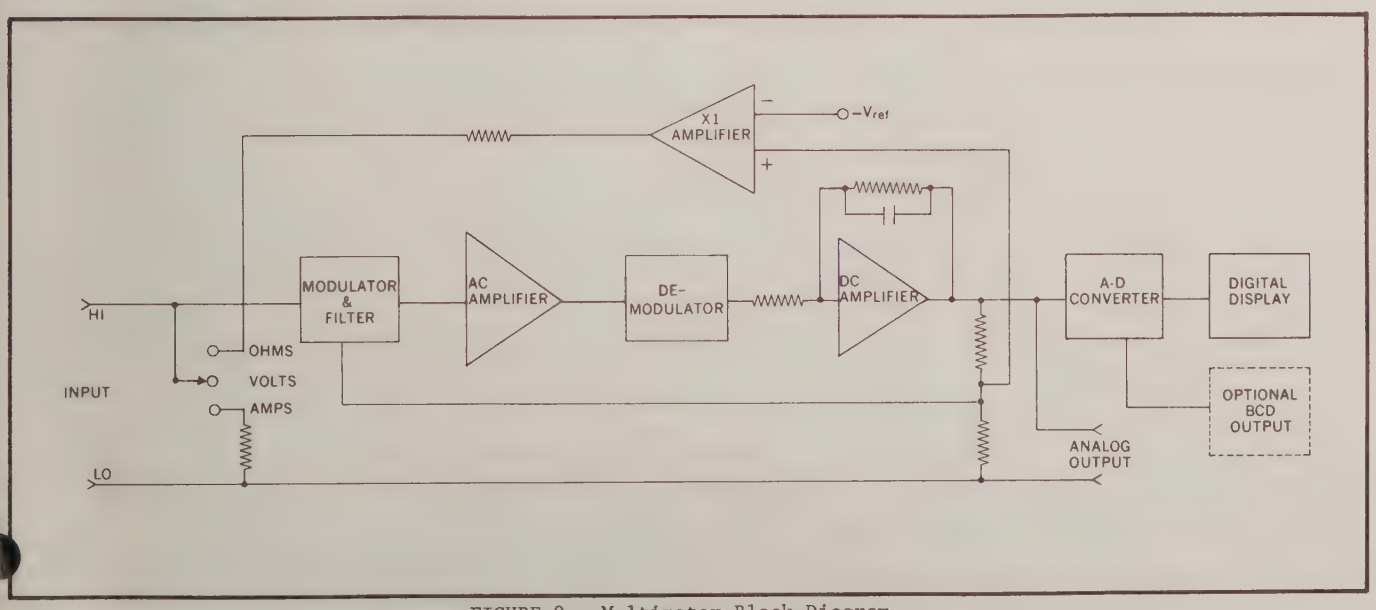


FIGURE 9. Multimeter Block Diagram.

3-3. ANALOG AMPLIFIER CIRCUITRY.

a. General. The circuits described in this section are located on the following sub-assemblies:

1. Mother Board, PC-254.

2. Analog Amplifier, PC-251.

3. Connector Board, PC-255.

b. Voltage Amplifier Circuit. The voltage amplifier circuit is composed of a chopper amplifier with fractional feedback. The feedback resistors are selected by the Range Switch so as to maintain low feedback current. The feedback network, composed of resistors R513, R516, R519, and R703, is formed from the output of the d-c amplifier to the low side of the modulator.

1. Input Resistor Divider. The chopper amplifier has a minimum gain of 10 and a full-scale output voltage of ±1 volt. Thus it is necessary to attenuate signals greater than 100 millivolts to prevent saturation of the chopper amplifier. The input attenuator resistors R101, R102, and R103 through R111 are switched by the Range Switch S101.

2. Filter Network. The filter network provides NMRR as specified for line frequency voltages (either 50 or 60 Hz). The filter is a 2-section RC ladder filter composed of resistors R501 and R502 and capacitors C501 and C502.

3. Modulator Circuit. The modulator circuit utilizes MOS FET chopper switches to provide low offset voltage and current, low input noise, and low drive power. A series-shunt chopper configuration maintains high input impedance. Transistors Q701 and Q702 form the chopper.

4. A-C Amplifier. The a-c amplifier is a low noise amplifier composed of transistors Q703 and Q704 and an integrated circuit QA702.

5. Demodulator Circuit. The demodulator utilizes an FET shunt switch which is synchronized with the input modulator. The FET Q705 switching action creates a rectified d-c signal with a large chopper frequency a-c component. Resistors R717 and R718 with capacitor C710 provide a filtering action of the demodulated signal.

6. D-C Amplifier. The d-c amplifier utilizes an integrated circuit QA703 to provide d-c gain and capability of up to 1 milliampere at the analog output.

7. Chopper Drive Circuit. The chopper frequency signal is derived from the Oscillator circuit. Transistors Q706 and Q707 provide opposite phase square waves used to drive MOS-FET chopper transistors Q701 and Q702. Transistor Q708 provides a demodulator drive signal for FET Q705 which is synchronous with the modulator drive signals. Flip-Flop circuits QA701A and QA701B divide down the 909.09 Hz from the oscillator by 4:1 for a chopper drive of approximately 227.3 Hz.

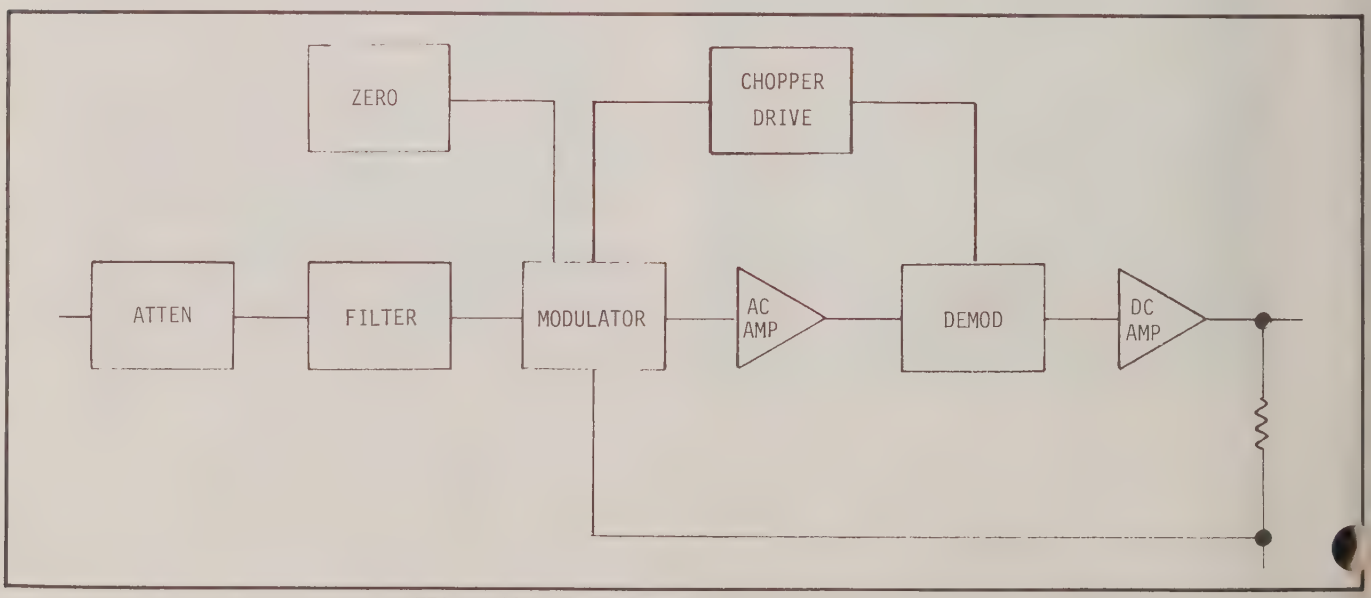


FIGURE 10. Analog Amplifier Block Diagram.

8. Zero Adjustment Circuit. This circuit provides limited adjustment of zero offset. It is composed of potentiometer R505 and resistors R503, R504, R506, R508, and R509 (See schematic 26244E) and R1215, R1216 (see schematic 26242D).

c. Ammeter Circuit (DMM Mode). The instrument utilizes the chopper amplifier described above with various Range shunt resistors R116 through R122. The chopper amplifier functions as a voltage amplifier to provide an analog recorder output and drive for the A-to-D converter.

TABLE 3-1.

Full Range Sensitivity	Shunt Resistor (Ohms)	Full Range Voltage Drop
1×10^{-7}	10^5	10 mV
1×10^{-6}	10^4	10 mV
1×10^{-5}	10^3	10 mV
1×10^{-4}	10^2	10 mV
1×10^{-3}	10	10 mV
1×10^{-2}	1	10 mV
1×10^{-1}	.1	10 mV
1	.1	100 mV

d. Ohmmeter Circuit (DMM Mode). The instrument provides a constant-current using a voltage reference amplifier and series resistor R. The reference voltage E limits the open-circuit voltage to 1.5 volts maximum. The voltage reference is composed of integrated circuit QA704 and reference diode D702.

e. Milliohm Source. (See schematic 26242D)

1. AC voltage from T1201 is rectified by bridge D1201, filtered and supplied to the pre-regulator QA1201. This is a three-terminal 15 volt regulator. The 15 volt output is connected through the series pass transistor Q1201 to the Hi terminal of the mΩ Source, J1204.

2. The pass transistor is controlled by the opertional amplifier QA1202. One input to QA1202 is +10 volts (referred to power supply common). This is obtained from two zener diodes, D1202 and D1203 and a divider network R1202, R1203, and R1204. R1203 is a potentiometer to permit compensation for the tolerance of the zener diodes and the offset voltage of QA1202. The other input is the voltage drop across the selected current sensing resistor, one of R1205 through R1209, which is in series with the LO terminal, J1203.

3. When the current regulator is in balance, the drop across the current sensing resistor is equal to the reference voltage and the current delivered by the mΩ Source terminals is the proper value.

4. If the current source has no load, the voltage across the terminals will approach 15 volts. When testing switches or relay contacts for "dry circuit" applications, the voltage must be limited to 20mV or less. This is done by setting S1202 in the Volt Limit position. The output current is then divided between the load and one of the volt limit resistors, R1210 through R1214. Even with open-circuited load, the voltage at the source terminals will not exceed 20mV.

3-4. ANALOG-TO-DIGITAL CONVERTER OPERATION.

a. General. The analog-to-digital converter uses a dual-slope technique which has inherent line-frequency noise rejection. The analog signal is applied to the integrator for 200 milliseconds which is an even multiple of the line frequency of 50 or 60 Hz. The analog signal is then removed from the integrator input. The voltage on the integrator is then driven to zero to complete the voltage-to-time conversion. The time interval to reach a "Zero Crossing" is counted and displayed on the "Digital Readout" in proportion to the original analog signal. Before the sequence is repeated, the integrator is rezeroed.

b. The A-to-D Converter is composed of eight major circuits as follows:

1. Oscillator or Clock
2. BCD Counter
3. Program/Decoder
4. Integrator
5. Zero Crossing Detector
6. Buffer/Storage Register
7. Decoder/Driver
8. Numerical Readout.

c. Oscillator or Clock. The Oscillator produces pulses at a rate of 10 kilohertz for either 50 or 60 Hz operation.

d. BCD Counter. The BCD Counter counts the Clock pulses with a total range of 5000 counts. The Counter is composed of 4 individual counters designated 1, 10, 100, and 1000.

1. The "1", "10", and "100" counters have a capacity of ten counts each.

2. The "1000" counter has a capacity of five counts.

3. The total capacity of all four counters is 5000 counts.

e. Program/Decoder. The Program/Decoder circuit produces event commands to control the overall sequence of events for a complete A-to-D conversions.

TABLE 3-2.
Summary of Event Commands

Command	Function
2	ZERO
3,4	INTEGRATE
0,1	COUNT

f. Integrator. The Integrator circuit operation is composed of three periods.

1. Zero Period. During this period the integrator amplifier is zeroed by a feedback rezeroing circuit as shown in Figure 12. Switches S_a, S_b, S_d are open to prevent integrator charging.

2. Integration Period. During this period, switches S_b, S_c, and S_d are open. Switch S_a is closed to permit charging by the analog voltage for an even multiple of the line frequency.

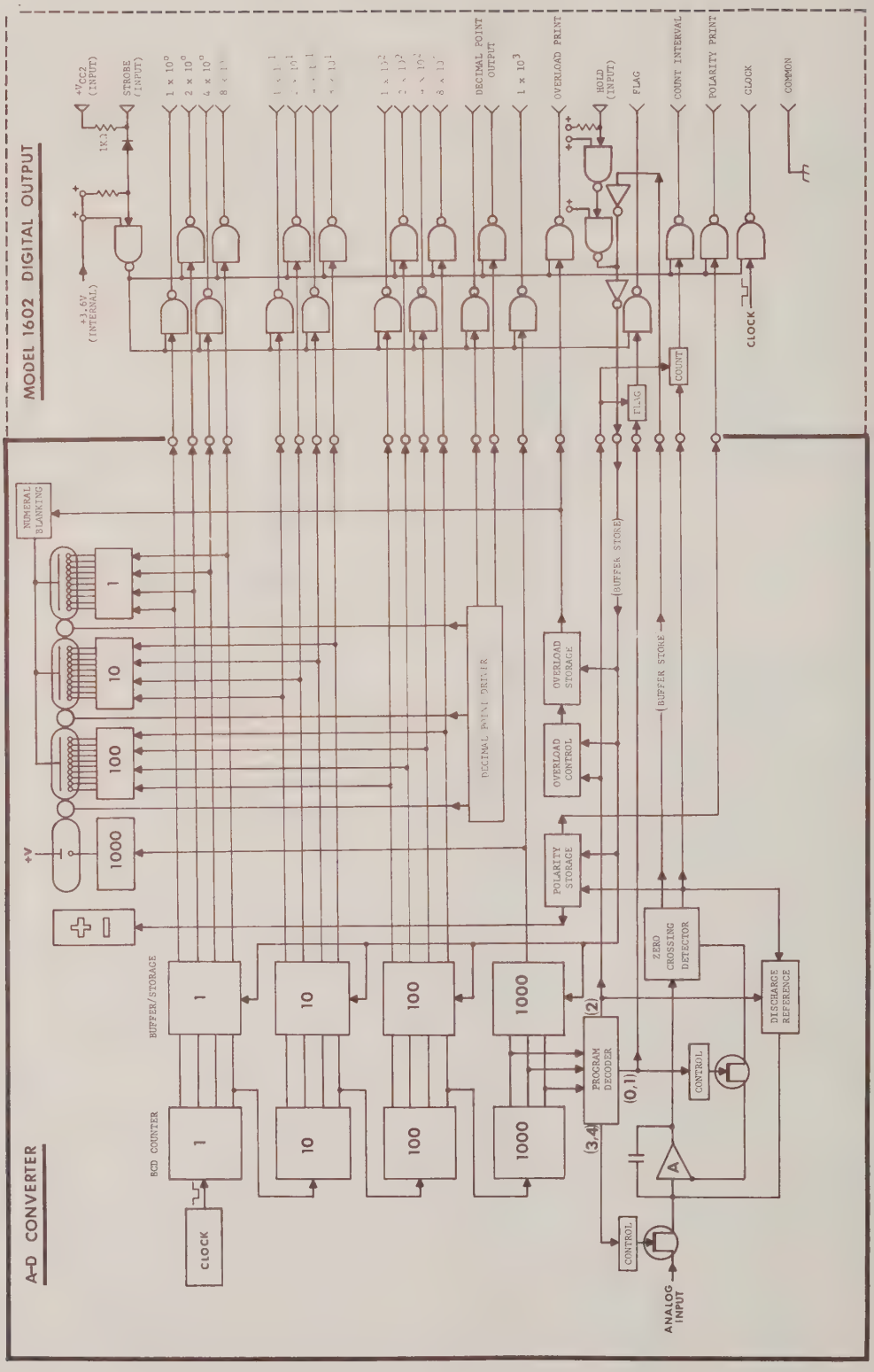


FIGURE 11. A/D Converter Block Diagram.

3. Discharge Period. During this period, switch S_a is open to prevent further charging by the analog signal. Either switch S_c or S_d is closed to drive the Integrator voltage to zero. A reference current of opposite polarity to the input current is applied through either switch S_c or S_d. The Discharge Period ends when the Zero Crossing Detector circuit detects a zero Integrator output.

g. Zero Crossing Detector. The Zero Crossing Detector circuit provides a "High" or "Low" level output depending on the polarity of the detected input. Refer to Table 3-3 for a description of voltage outputs of the Zero Crossing Detector.

TABLE 3-3.
Zero Crossing Detector Output Levels.

M	N	B	C
0V	-0.5V	+1.5V	0V
0V	+3.5V	0V	+1.5V

h. Buffer/Storage Register. The Buffer/Storage Register is composed of "flip-flops" arranged to copy the states of the various BCD counters. The Buffer/Storage Register requires a Buffer Store command before any information can be transferred. The "flip-flop" circuits provide coded information for Decoder/Driver and BCD outputs.

i. Decoder/Driver. The Decoder/Driver circuit decodes the BCD information from the Storage Register into ten-line decimal code. The Driver circuit then drives the proper numeral in each of the Numerical Readout tubes.

j. Numerical Readout. The Numerical Readout consists of four numerical indicators and one polarity indicator driven by the Decoder/Driver, Polarity and Overload Drivers.

k. Summary of Operation. The operation of the A-to-D Converter can be described by considering a typical conversion cycle. The Clock provides pulses at a rate of 10 kilohertz. The BCD Counter serves as a master timing control for the A-to-D conversion cycle. The timing is accomplished by the "1000" counter which has five coded states, namely 0, 1, 2, 3, and 4. The Program/Decoder controls the sequency of commands based on the coded states from the BCD Counter. The decoded commands are described as shown in Table 3-2. The "2" command initiates the integrator ZERO period which removes any residual charge on the integrator capacitor. The "3,4" command initiates the INTEGRATE period which permits an integration of the analog signal. At the end of the INTEGRATE period, the "0,1" command initiates the COUNT period. When the "3,4" command is given, the integrator is charged by the analog signal for a period of 200 milliseconds. When the "0,1" command is given, the analog signal is removed and the integrator output is driven to zero by a reference current. The Zero Crossing Detector senses a zero crossing of the Integrator output and removes the reference current. The Detector provides outputs as shown in Table 3-3. The +1.5 volt levels are provided for control of the Integrator and Polarity Storage Register. A pulse command is also produced to initiate a Buffer/Store. When the Buffer/Store command is given, the Buffer/Storage Register copies the BCD Counter states at that instant of time. The BCD coded information in the Register is then available for the Decoder/Driver and external printout. The Decoder/Driver decodes the Buffer/Storage output and drives the Numerical Readout for a digital display. The conversion cycle is completed when the BCD Counter reaches 2000 counts and the Program/Decoder provides a "2" command to initiate a new conversion cycle.

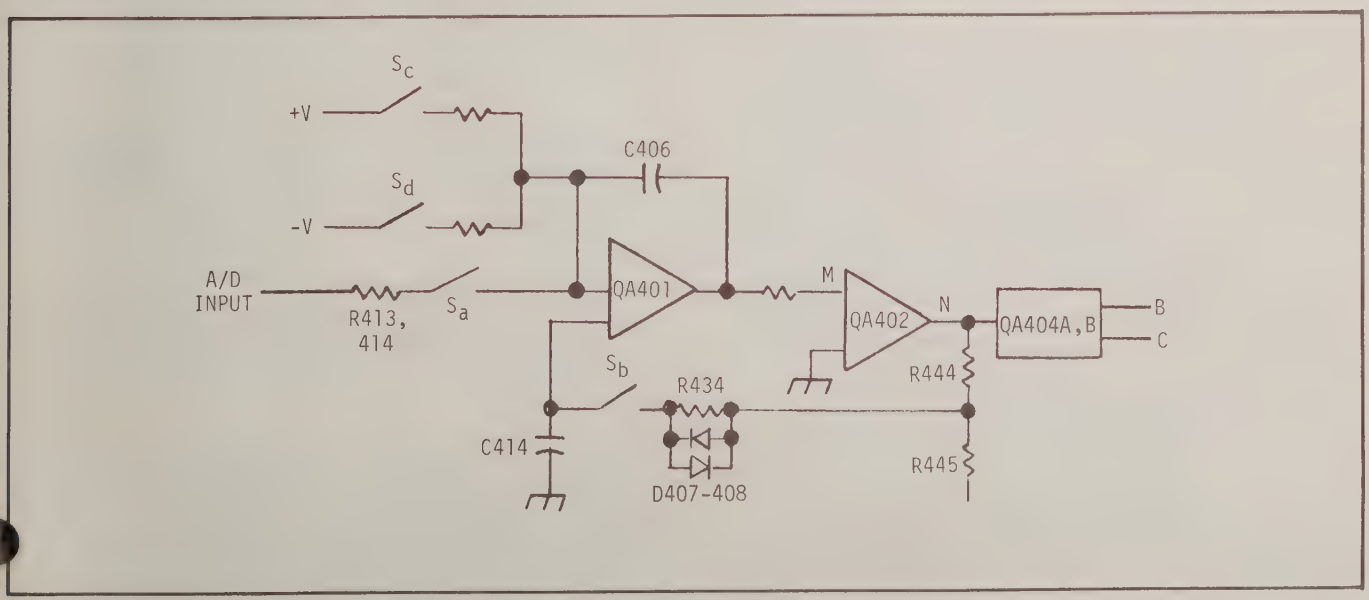


FIGURE 12. Integrator Simplified Diagram.

3-5. ANALOG-TO-DIGITAL CONVERTER CIRCUITRY.

a. General. The circuits described in this section are located on the following sub-assemblies.

1. Tube Board, PC-248
2. Integrator Board, PC-250
3. Oscillator Circuit, PC-254.

b. Oscillator Circuit. The Oscillator circuit is located on a portion of printed circuit assembly PC-254. Transistors Q601 and Q602, capacitors C601, C602, and C603 and resistors R606 and R607 form an oscillator. Potentiometer R605 is used to provide internal screwdriver adjustment of the oscillator frequency. Transistor Q603 serves as an emmitter-follower to reduce output impedance. The chopper drive is obtained by dividing down the oscillator frequency from 10 Kilohertz to 909.09 Hz using integrated circuit QA801, a 11:1 Divider circuit.

c. Tube Board. The Tube board contains portions of five major circuits: the BCD Counter, the Program/Decoder, the Buffer/Storage Register, the Decoder Driver, and the Numerical Readout.

1. BCD Counter.

a) The Decade Counters designated "1", "10", and "100" are composed of individual integrated circuit modules QA308, QA309, and QA310 respectively.

b) The "1000" Counter is composed of integrated circuit modules QA301A, QA302A, and QA302B.

2. Program/Decoder. This circuit is composed of gates QA304A, QA304C, QA305 (B, C, D, E, F) QA306A and QA307B.

3. Buffer/Storage Register. This circuit is composed of integrated circuit modules QA311, QA312, and QA313.

4. Decoder Driver. This circuit is composed of integrated circuits QA314, QA315, and QA316.

5. Numerical Readout. V301, V302, V303 are Readout Tubes for Units, Tens, and Hundreds respectively.

6. Other circuits contained on the Tube Board are described as follows:

a) Overrange Indicator Circuit. This circuit is composed of integrated circuit module QA301B, transistor Q301 and overload indicator DS301.

b) Polarity Indicator Circuit. This circuit is composed of transistors Q305 and Q306 and Polarity indicator module DS302.

c) Display Rate/Hold Circuit. Gates QA303 (A, B, C, D) and QA304B, QA306B, and QA307A provide capability for Display Rate and Hold functions when used with additional Output Buffer circuits.

d. Integrator Board. The Integrator Board contains portions of three major circuits: the Integrator circuit, the Zero Crossing Detector Circuit, and the Feedback Rezeroing Circuit.

1. Integrator Circuit. The operation of the Integrator is controlled by the positions of switches S_a, S_b, S_c, and S_d (as shown in Figure 12). Switch S_a is Q401. Switch S_b is transistor Q411. Transistors Q404, Q405, Q408, Q409, and Q410 are control circuits arranged to control the proper FET switches depending on the signals at pins 12 and 13. The integrator amplifier consists of transistors Q402 and Q403 and integrated circuit QA401. The feedback capacitor is C406. Switches S_c and S_d control the current for 9-volt zener diodes D401 and D402. Resistors R403, R404, R405, R409, R410, and R411 are full-scale calibration resistors. Potentiometers R402 and R408 are internal screwdriver calibration adjustments.

2. Zero Crossing Detector Circuit. The high gain amplifier is composed of cascaded amplifiers QA402 and QA403. Diode D411 provides a 6-volt bias supply for QA403 and the output resistor network R444 and R445. The level-splitter circuit consists of diodes D414 and D415, resistors R443 and R446 and gates QA404 (A and B).

3. Feedback Rezeroing Circuit. This circuit provides rezeroing of the Integrator circuit using negative feedback from the Zero Crossing Detector output. Transistor Q411 is the equivalent of Switch S_b in Figure 10. Resistor R434 and capacitor C414 form a feedback-loop filter circuit. Diodes D407 and D408 provide fast response for large input offsets due to input overloads.

3-6. POWER SUPPLIES.

a. ±15 Volt Supply.

1. The 15 volt supplies tap a-c power from a secondary winding of transformer T201. Diodes D203 (A, B, C, and D) and capacitors C204, C205, C209, and C210 compose a full-wave rectifier with filtering.

2. The +15 volt regulator circuit utilizes integrated circuit QA201 which drives transistor Q206 to series regulate the output voltage. Potentiometer R209 provides calibration adjustment of +15 volt supply. (Internal screwdriver adjustment).

3. Transistors Q211 and Q212 form a differential amplifier which compares the voltage at R218 with respect to low. The difference voltage is amplified by transistor Q210 and fed to Darlington transistor pair, Q207 and Q208, which series regulate the -15 volt output. Transistor Q209 limits the current output to approximately 200 milliamps.

b. +3.6 Volt Supply.

1. The +3.6 volt supply taps a-c power from a secondary of transformer T201. Diodes D201 and D202 and capacitor C201 form a full-wave rectifier with filtering.

2. Transistor Q205 amplifies the difference between the +3.6 output and a reference voltage derived from the +15 volt supply and determined by resistors R203 and R204. The difference voltage is applied by transistor Q204 which drives a Darlington transistor pair, Q201 and Q202. The Darlington pair series regulates the +3.6 volt output.

3. Transistor Q203 limits the output current to about 3 amperes.

c. +210 Volt Output. The +210 volt supply is an unregulated voltage supply using the half-wave filtered voltage at diode D206 and capacitor C212.

d. +170 Volt Output.

1. Regulator. The +170 volts is derived from the +210 volts at emitter of Q302 which series regulates the +170V. Transistor Q303 provides a reference for the base of transistor Q302.

2. Blanking Circuit. This circuit controls the +170 voltage for the three right hand readout tubes The "Q" output of QA307B drives the base of transistor Q304 for normal regulator operation. When an overload occurs, the "Q" output is low turning off transistor Q304. This results in a drop of the +170 volt output causing blanking of the readout tubes.

e. Milliohm Source Supply. The primary windings of T1201 are connected in parallel with transformer T201. AC power for both is supplied from line connector P201 via fuse F201 and switch S1201. The dual primary windings are connected in parallel by switch S202 for 117 volt operation and in series for 234 volt operation. In addition, fuse F202 is connected in the circuit for 234 volts.

3-7. ELECTRONIC TRIP CIRCUITRY. The two trip circuits in the 164TT are essentially the same, differing only in that the LO trip output transistor is an NPN type while the HI trip output transistor is a PNP. The analog signal at J103 (schematic 26244E) is a one volt signal for full scale input to the DMM. This signal is applied to the inverting inputs of QA1301 and QA1302 through resistors R1309 and R1314. The reference voltage used to determine the trip point is derived from zener diode D1301. The HI limit is set by R1307 and the LO limit by R1308. These limit voltages, either of which may be set from -2 volts to +2 volts, are applied to the non-inverting inputs of QA1301 and QA1302 through resistors R1310 and R1315. If the HI limit is set at +1.0 volt and the analog output is less than +1.0 volt, the output of QA1302 will be positive and the HI output transistor Q1302, will be cut off. When the analog output exceeds +1.0 volt, the output of QA1302 will become negative, turning on Q1302 and causing relay K1302 to close and lighting the front-panel trip lamp DS1302. A small voltage is developed across R1320 which is connected back to the non-inverting input of QA1302 through resistor R1317. This provides some hysteresis so the relay will not drop out until the input is somewhat less than the trip point. The LO limit circuit functions the same way except the output of QA1301 is normally negative. Since the driver transistor Q1301 is an NPN, it is cut off by this voltage. Setting the trip points is done by holding in S1301 or S1302 and adjusting the corresponding limit control, R1307 or R1308. When the HI limit switch S1301 is operated, the analog output of the DMM is disconnected from the A/D converter. The output of QA1302 is connected to the A/D converter and also to the inverting input of QA1302, making it into a unity-gain voltage follower for the trip point voltage applied to the non-inverting input. Thus the A/D converter indicates the magnitude of the trip point voltage.

SECTION 4. ACCESSORIES

MODEL 1601 AC-DC PROBE

GENERAL. The Model 1601 is a combination ac-dc probe that enables the user to measure voltages from 45 Hz to 45kHz when used with the Model 164. The slide switch (S101) can be used to select either AC mode or straight-through DC Mode.

SPECIFICATIONS:

DC MODE: Straight-through probe does not alter any Model 160 or 163 specifications except: 1. 150 picofarads input capacitance, 2. 0.5 ampere maximum current, 3. 0.3 ohm resistive offset, 4. ± 20 microvolts thermal offset.

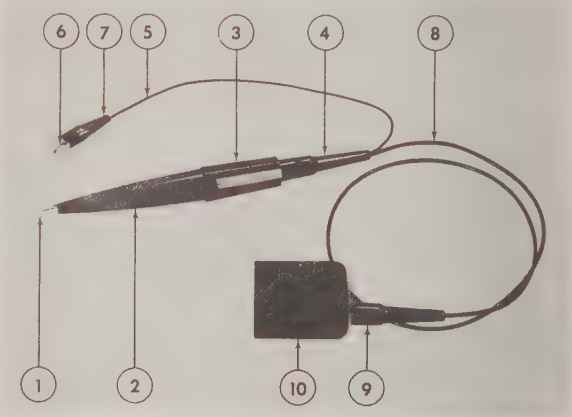
AC MODE (Voltage only):
- ACCURACY (400 Hz): ±1% of reading or ±0.1 volt, whichever is greater (rms of sine wave to dc conversion).
- FREQUENCY RESPONSE: -2% at 45 Hz and 45kHz.
- RANGE: 250 volts rms maximum.
- MAXIMUM OVERLOAD: Peak ac plus dc bias must not exceed 400 volts.
- INPUT IMPEDANCE: 0.5 megohm, shunted by less than 20 picofarads.
- OUTPUT IMPEDANCE: Output must be shunted by 10.2 megohms ±1% for rated accuracy (Model 160 and 163 impedance on 1000, 100 and 10-volt ranges). 10% variation in the 10.2 megohms causes 1% additional error.

CONNECTOR: Shielded Banana Plug

DIMENSIONS, WEIGHT: 6" long x 3/4" diameter (150 x 20 mm), 3-ft. (1 m) cable, net weight 1/4 pound (0.1 Kg).

MECHANICAL PARTS LIST:

Item No.	Description	Keithley Part No.
1	Tip	24654B
2	Body, Front	24656C
3	Body, Rear	24655C
4	Strain Relief	18676B
5	Cable, Ground (13" long)	SC-33
6	Clip, Alligator (Ground)	AC-10
7	Insulator (Black)	AC-11
8	Cable (40" long)	SC-30
9	Strain Relief	18676B
10	Can Shield	25128A



ELECTRICAL PARTS LIST: (See schematic 24669C)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.
J101	Banana Plug (2 req'd)	74970	108-750-2	BG-3
S101	Switch, AC-DC	80164	-	SW-334
C101	Capacitor, .047μF	97419	M2W-F	C197-.047M
C102	Capacitor, 0.1μF	13050	MW1A	C86-.1M
D101	Transistor	07263	2N3565	TG-39
D102	Transistor	07263	2N3565	TG-39
D103	Diode	04713	1N4006	RF-38
R101	Resistor, 3.92MΩ	91637	DC-1/4	R178-3.92M
R102	Resistor, Selected in Test	07716	CEA	R88
R103	Resistor, 1MΩ	91637	MFF-1/8	R179-1M
R104	Resistor, 100Ω	44655	RC07	R76-100

MAINTENANCE: Since the probe assembly should provide good service with normal handling, no maintenance is usually necessary. The probe body (Items 2 and 3) is fastened together at the factory using a special solvent. Therefore the probe should not be disassembled. If repair is necessary, contact the Keithley Representative in your area.

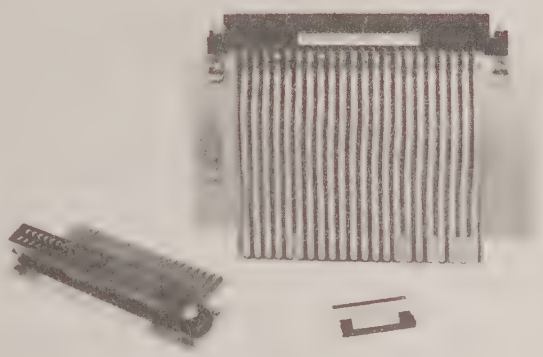
Model 1603 Extender Card Kit

Description:

The 1603 Kit consists of two types of printed circuit board extender cards and a shorting adapter.

Parts List:

1 Extender Card, 44-pin, Keithley No. 24681C
2 Extender Card, 22-pin, Keithley No. 24570B
3 Shorting Adapter, Keithley No. 24789A



Application:

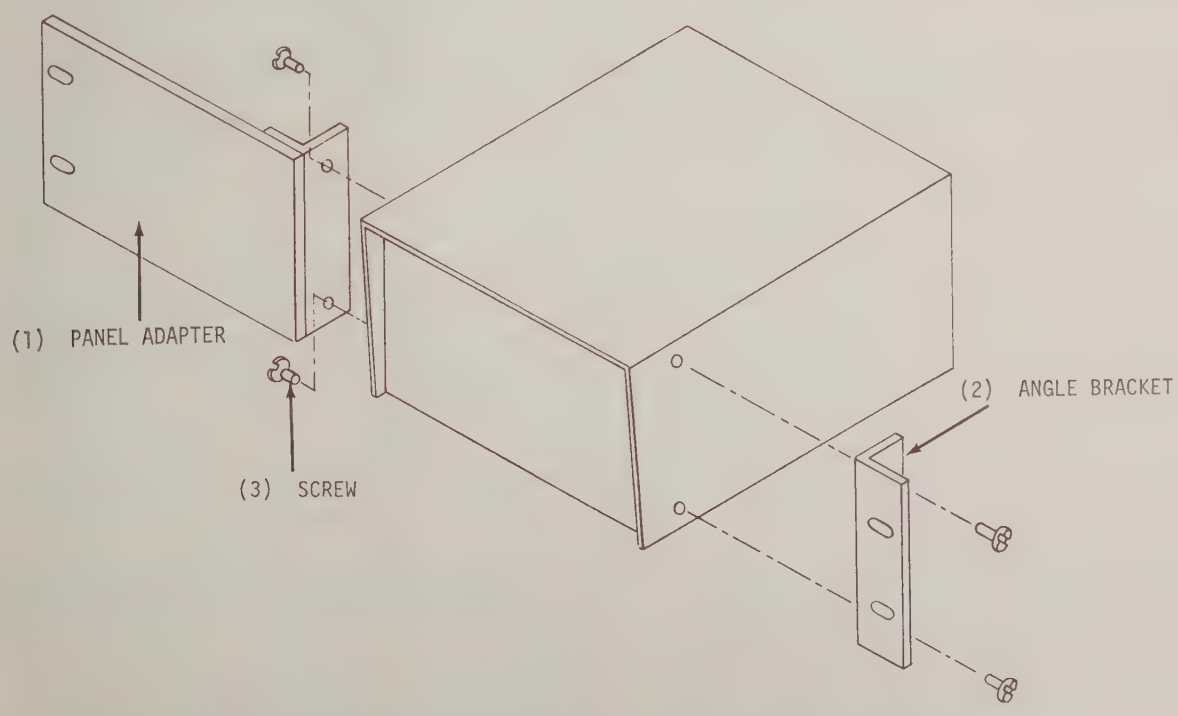
These extender cards facilitate testing and troubleshooting of Models 164 and 164TT. Access to all pin connections is provided. The shorting adapter is not useable with Models 164 and 164TT.

Model 1000 Rack Mounting Kit

General: The Keithley Model 1000 Rack Mounting Kit includes all necessary parts for rack mounting one instrument in a 19 inch panel. Rack height is 5-1/4 inches with 11 inches depth measured from the front panel.

Parts List:

Item	Description	Keithley Part No.
1	Panel Adapter	26063B
2	Angle Bracket	26062B
3	Screw (4 required)	#8 32x3/8", Phil Hd.



SECTION 5. SERVICING

5-1. GENERAL. This section contains procedures for servicing the instrument in the event of a malfunction.

5-2. SERVICING SCHEDULE. This instrument requires no periodic maintenance beyond the normal care required for high-quality electronic equipment.

5-3. PARTS REPLACEMENT. Replace components using only those parts specified in the REPLACEABLE PARTS LIST or their equivalents.

5-4. ASSEMBLY

> WARNING
>
> Use care when troubleshooting an instrument connected to line power and/or with Power switch on. Whenever resistance checks are made, remove all power to the instrument and discharge power supply capacitors through a low value resistor.

a. Top Cover Assembly. To gain access to test points and adjustments on printed circuit board PC-254, remove the top cover by unfastening six slotted-head screws as shown in Figure 21.

b. Chassis Assembly. To gain access to the remaining printed circuit boards the following procedure should be used.

1. Remove the front panel Range knob assembly as shown in Figure 14. Loosen the two set screws holding the switch coupler to the switch shaft using a 1/16 hex size (Allen Head) screw driver. Figure 13 shows the proper orientation of the Range knob for reassembly.

2. Remove the front panel Allen Head screws in two places as shown in Figure 14 using a 3/32 hex size screw driver.

3. Remove the rear panel Phillips head screws in two places as shown in Figure 14.

4. Remove connector J906 which is wired between PC-254 and PC- 348. Replace connector with longer jumper cable (furnished in the Model 1603 Extender Card Kit) which will apply power to the instrument.

5. Separate the circuit board assembly from the chassis as shown in Figure 15.

c. Printed Circuit Board Installation. The location of all circuit boards is shown in Figure 16. To gain access to circuit boards PC-248, PC-250, and PC-255 the following procedure should be used.

1. Remove the two Phillips head screws from the underside of PC-254 as shown in Figure 16.

2. Remove the slotted screw and nut holding PC-248 and PC-250.

3. Remove the long slotted screw and fastener as shown in Figure 16.

4. Remove the two standoffs holding PC-248 and PC-250.

5. Remove circuit board PC-255 and replace with Extender Card 24681C (from Model 1603 Extender Card Kit).

5-5. CALIBRATION CONTROLS.

a. Offset Current Adjust (R733). This control is a screw driver adjustment accessible from the bottom cover as shown in Figure 18.

b. Ohms Cal Adjust (R738). This control is a screw driver adjustment accessible from the bottom cover as shown in Figure 18.

c. DC Balance Adjust (R722). This control is an adjustment accessible from the bottom cover as shown in Figure 18. Caution! Use an insulated screw driver to avoid contacting the chassis.

d. 15V Adj. (R209). This control is located on PC-254. Remove the top cover for access to the control.

e. CLOCK Adj. (R605). This control is located on PC-254. Remove the top cover for access.

f. 1V, 10V, 100V, 1000V Controls (R111, R108, R106, R104). These controls are also located on PC-254.

g. +CAL, -CAL Adjust. These controls are located on PC-250.

5-6. COMPONENT LAYOUTS AND OUTLINE DRAWINGS.

a. Component Layouts. The component layouts identify all parts on the printed circuit boards using circuit designations from the schematic diagrams.

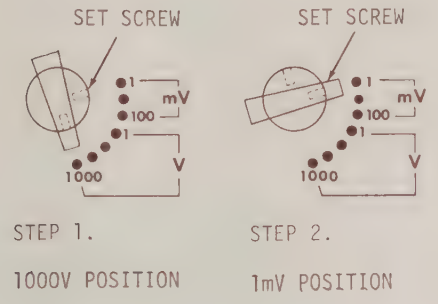


FIGURE 13. RANGE Knob Assembly.

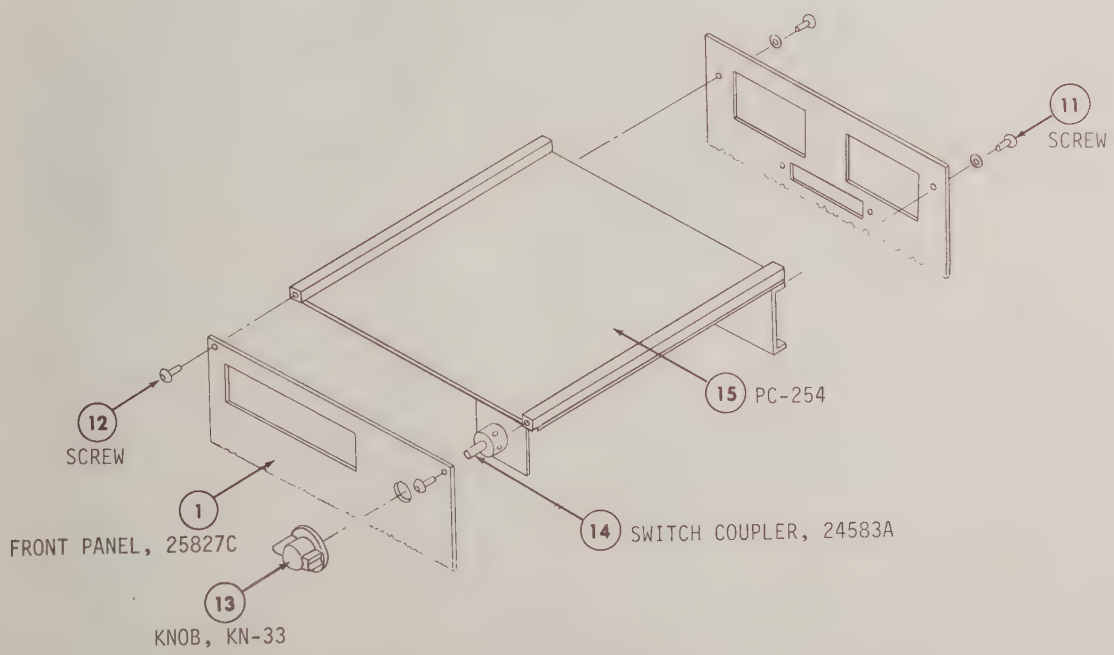


FIGURE 14. Chassis Assembly.

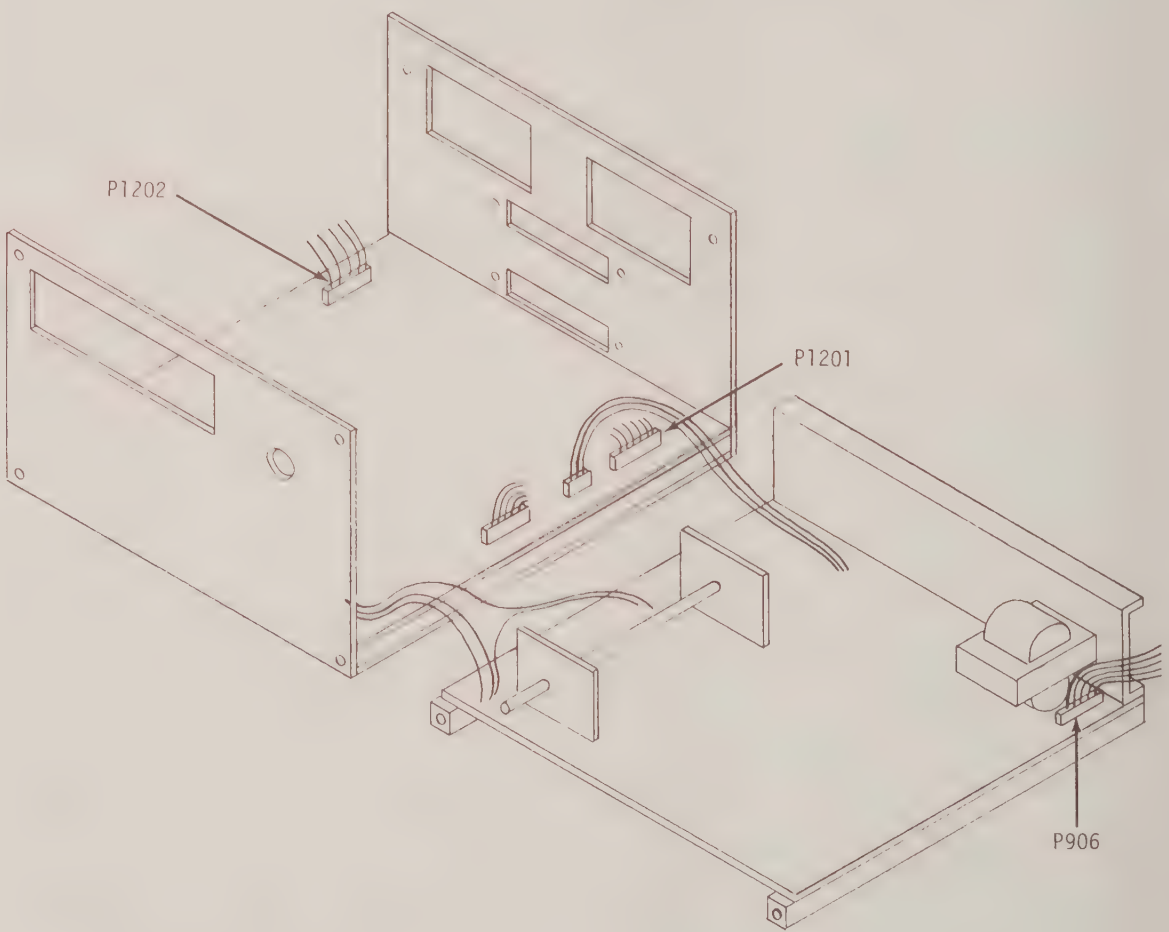


FIGURE 15. Servicing of Chassis.

TABLE 5-1.
Chassis Part Identification

Item No.	Description	Keithley Part No.
1	Front Panel	25827C
11	Screw, Hex socket	#8 x 3/8
12	Screw, Phillips head	#8 x 5/8
13	Knob	KN-33
14	Switch coupler	24583A
15	Printed Circuit Board	PC-254
16	Switch, S101	SW-319
17	Cable harness	---
20	Printed Circuit Board	PC-251
21	Printed Circuit Board	PC-255
22	Printed Circuit Board	PC-248
23	Printed Circuit Board	PC-250
24	Screw, slotted	#4 x 2-1/4
25	Fastener, hex nut	#4-40
26	Standoff (2 req'd)	24193A
27	Screw, Phillips head	#6 x 5/16
28	Screw, slotted	#6 x 5"
29	Fastener	FA-107

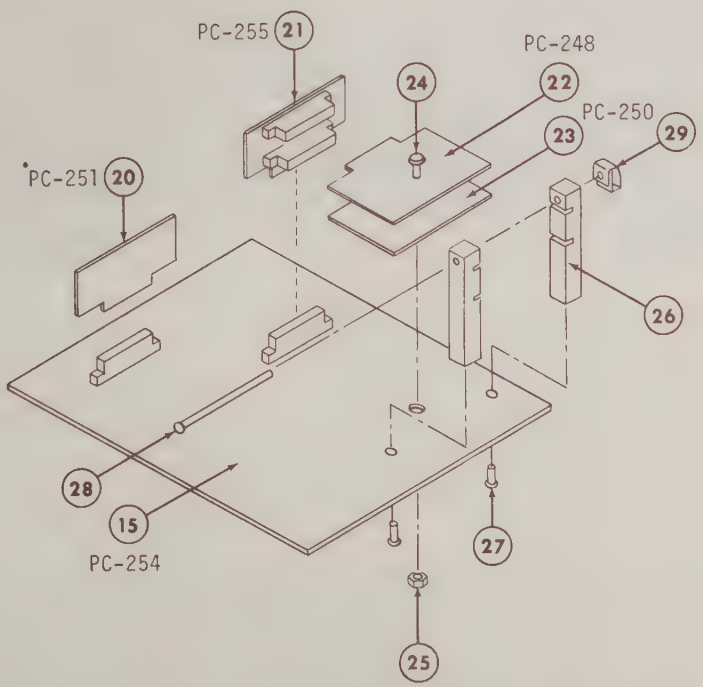


FIGURE 16. PC Board Locations.

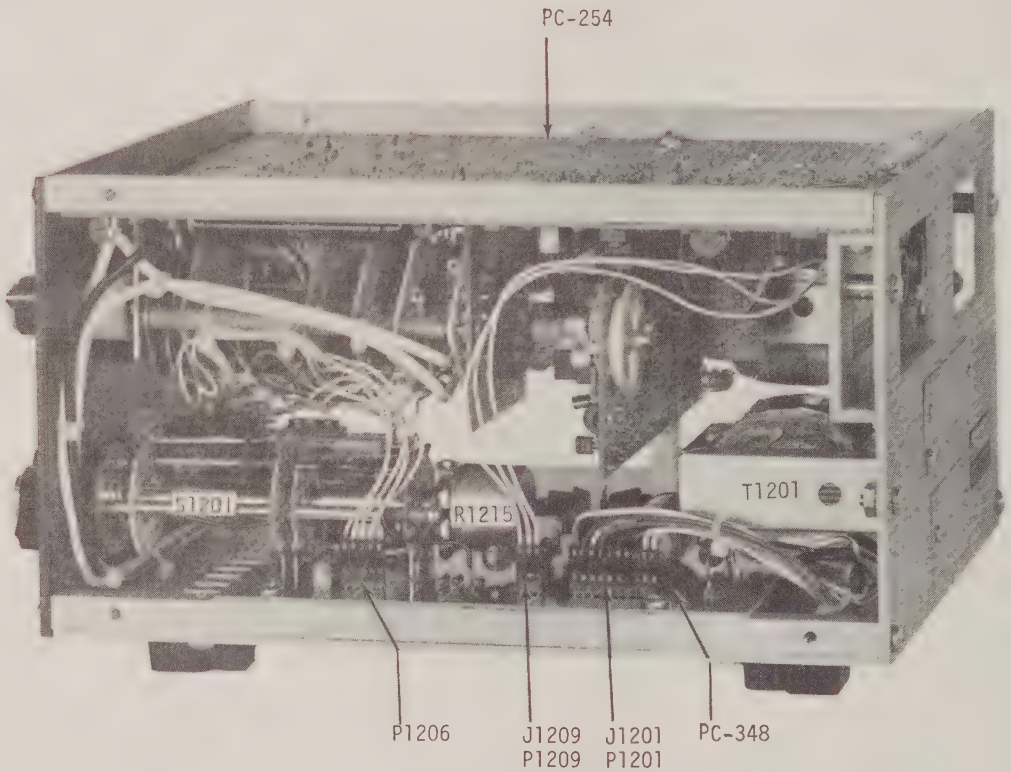


FIGURE 17. Side View of Chassis.

TABLE 5-2.
Trouble-Shooting Procedure

Difficulty	Probable Cause	Solution
No front panel display illimination.	Power failure	Check fuse. If blown, check for an internal short (broken wire, loose hardware, etc.). Replace fuse by removing top cover and unsoldering pig-tail fuse.
" "	210V supply failure	Check 210V supply voltage on PC-254. If low, check rectifier diode D206. Replace with Keithely Part No. RF-17.
" "	Line switch set at 234V with 117V line input.	Set switch to 117V.
Overload Indication when input is shorted.	Analog amplifier out of balance.	Check integrated circuit QA703 on analog board PC-251. Replace with Keithley Part No. IC-2. If difficulty remains, check MOS FET transistor Q701 and Q702. Replace with Keithley Part No. TG-51. NOTE: These transistors are sensitive to static charges. Therefore, drain static charge from hands and/or tools using a foil grounding surface. Disconnect the soldering iron from power before using.
" "	Transistors Q402 and Q403	Check for zero voltage level on pin 6 of integrated circuit QA401. If not at zero, replace transistors with Keithley Part No. TG-71.
" "	Oscillator Circuit (Clock)	Check CLOCK frequency at CLOCK test point. Frequency should be 10kHz ±20 Hz. If out of tolerance, recalibrate as in Section 6. If clock frequency is missing, check transistors Q601, Q602, and Q603. Replace with Keithley Part No. TG-62.
Ohms ranges inaccurate. (Voltage ranges are normal)	Ohms reference amplifier	Check integrated circuit QA704. NOTE: Integrated circuit may have failed due to voltage applied in ohms mode. Replace QA704 with Keithley Part No. IC-2. Also replace resistor R745 with Keithley Part No. R168-10K. Recalibrate OHMS circuit. Select R739 as necessary.
Current reading inaccurate on one range only	Shunt resistor out of tolerance.	Replace shunt resistor for that particular range. Resistors R116 through R122.
Overrange "1" not lighted when it should indicate.	Transistor Q301 or integrated circuit QA301.	Replace transistor Q301 if shorted from collector to emitter (Keithley Part No. TG-67). Otherwise, replace QA301 with Keithley Part No. IC-9.
Overrange "1" lighted continuously when it should not indicate.	Transistor Q301 or integrated circuit QA301.	Replace as above.
Polarity signs remain lighted or do not light at all.	Transistors Q305 and Q306. Integrated circuit QA305.	Replace transistors Q305 and Q306 with Keithley Part No. TG-67. Replace QA305 with Keithley No. IC-7.
Digital Readouts incorrect.	Decoder driver circuit	Replace either QA314, QA315, or QA316 with Keithley Part No. IC-3. (These integrated circuits are not soldered because of plug-in sockets.)
" "	Decade Counter circuit	Replace either QA308, QA309, or QA310 with Keithley Part No. IC-17
" "	Buffer Storage circuit	Replace either QA311, QA312, or QA313 with Keithley Part No. IC-16.

SECTION 6. CALIBRATION

6-1. GENERAL. This section contains procedures for checking the instrument to verify operation within specifications.

6-2. TEST EQUIPMENT. Use test equipment recommended in Table 6-1 for accuracy verification.

6-3. PROCEDURES.

a. Preliminary.

1. Warm-up Period. With Power Switch ON, allow the instrument to warm-up for a minimum of 30 minutes.

2. Power Supply Checkout. All the power supply voltages can be measured at test points on printed circuit board PC-254 as shown in Figure 18.

TABLE 6-2.
Power Supply Voltages

Nominal Voltage	Test Point	Voltage Limits
+15.00V dc	+15V	+14.95 to +15.05
-15.0V dc	-15V	-14.6 to -15.4
+3.6V dc	+3.6V	+3.4 to +3.8
+210V dc	+210V	+205 to +230
+170V dc	+170V	+165 to +175

b. Adjustments.

1. Power Supply. The +15V supply should be adjusted for +15.00V dc ±0.050V using potentiometer R209 on PC-254 as shown in Figure 18. The -15V and +3.6V supplies cannot be adjusted since the +15V supply is used as a reference voltage.

TABLE 6-1.
Test Equipment

Code Letter	Instrument Type	Specification	Manufacturer and Model No.	Use
A	Voltmeter, Digital	±1μV to ±1000V ±0.1% of reading	Keithley, Model 160	Zero Adjustment
B	Voltmeter, Differential	limit of error ±0.01% of reading or 10μV	Keithley, Model 662	Voltage Calibration Current Calibration Resistance Calibration
C	Voltage Source	.003% voltage mode 10, 100, 1000 volts	Fluke, Model 3330B Voltage Source	Voltage Calibration 10, 100, 1000 volts
			ESI type SR-1010 Divider Ratio	.001, .01, .1, 1 volts
D	Resistance Box	±.02% accuracy 10 megohms maximum	General Radio Type 1433 Decade Resistor	Resistance and Current Calibration
E	Current Source	.006% accuracy 0.1 mA to 100 mA	Fluke, Model 3330B Current Source	Current Calibration 0.1mA to 100mA ranges
		.003% voltage mode	Fluke, Model 3330B Voltage Source (1.01V)	Current Calibration
		.02% resistance accuracy	General Radio Type 1433 Decade Resistor	.001 to .01mA ranges

2. Clock Frequency. Measure the clock frequency at the "CLOCK" test point on PC-254 as shown in Figure 16. The frequency should be adjusted for a nominal 10kHz, ±20 Hz using potentiometer R605 on PC-254 as shown in Figure 18.

3. Zero Adjust. Temporarily disconnect front panel zero control R1215 by removing connector J1209 (located on PC-348). Place a shorting wire across the Input Terminals (red and black). Connect voltmeter (A) to the analog OUTPUT (J103). Adjust the rear-panel ZERO Control (R505) for zero on the 1 mV range.

4. The output should be adjusted to zero within ±1 millivolt.

5. DC Balance. With voltmeter (A) connected to the OUTPUT adjust the OFFSET CURRENT ADJ. Control (R733) for zero on the 1V range. The OUTPUT should be adjusted within ±1 millivolt on the 1mV range and within ±0.1 millivolt on the 1V range. Repeat the adjustments of R505 and R733 until the OUTPUT is within tolerance on both the 1mV and 1V ranges simultaneously.

NOTE

If the OUTPUT cannot be adjusted to within ±1mV on the 1mV range place a jumper between input low and the junction of R503 and C504 on PC-254. Then set RANGE switch to 100mV and adjust DC balance pot R722 (on PC-251) for zero at the OUTPUT. Remove jumper from R503 and repeat steps 4 and 5. After R505 and R733 are properly set, replace J1209 on PC-348 and adjust front panel zero R1215 for flashing zero on the 1mV range. Then remove the input short.

6. Analog Calibration.

a). Voltage Ranges. Connect voltmeter (B) to the analog OUTPUT. Connect voltage source (C) to the Input Terminals (red and black). Measure the analog OUTPUT voltage for each range as described in Table 6-3. On the 100mV, 10mV, and 1mV ranges wire jumpers are used for calibration. On the 1V, 10V, 100V, and 1000V ranges potentiometers R111, R108, R106, and R104 should be adjusted.

b). Resistance Ranges (Model 160 only). Concect decade rssistance box (D) to the Input Terminals. Measure the analog OUTPUT for each range as described in Table 6-4. Adjust the OHMS CAL potentiometer (R738) for an OUTPUT of +1V ±1.0 millivolt on the 1kΩ range only. The remaining resistance ranges cannot be adjusted.

c). Current Ranges (Model 160 only). Connect current source (E) to the Input Terminals. Measure tha analog OUTPUT for each current range as described in Table 6-5. No calibration adjustments can be made on any of the current ranges.

7. Digital Calibration.

a). Zero Check. Connect a shorting wire across Input Terminals. Adjust the front-panel ZERO Control so that the Digital Display reading is 0-0-0-0 on the 1mV range with the Polarity Indicator alternating plus and minus. Measure the analog OUTPUT voltage which should be within ±1 millivolt of zero.

DC BAL
OHMS CAL
OFFSET CURRENT ADJ
ZEROING
FOR CRITICAL MEASUREMENTS REQUIRING OFFSET LESS THAN A FEW MICROVOLTS AND/OR A FEW HUNDREDTHS OF A NANOAMPERE, THE FOLLOWING PROCEDURE SHOULD BE USED:
1 PERMIT THE INSTRUMENT TO WARM UP
2 SHORT THE INPUT WITH COPPER (A CLEAN PENNY WILL DO)
3 SWITCH TO THE 1 MILLIVOLT RANGE AND ADJUST THE REAR PANEL ZERO FOR A FLASHING (+ -)
4 SWITCH TO THE 1 VOLT RANGE AND ADJUST THE CURRENT OFFSET ADJ FOR A FLASHING (+ -)
5 REPEAT STEPS 3 AND 4

FIGURE 18. Chassis, Bottom View.

b). Full-Scale Indication. Connect voltage source (C) to the Input Terminals and adjust the source for +1.9992V measured at the analog OUTPUT. Adjust the -CAL Control (R402) so that the Digital Display has a reading which alternates between 1-9-9-9 and a blanked display (with only the over-range "1" lighted). Apply a negative input and adjust the +CAL Control (R408).

c). Linearity Adjustment. Connect an accurate voltage source (C) to the Input Terminals and adjust for an analog OUTPUT of +0.9992V on the 1V range. Verify that the Digital Display reading is 0-9-9-9. Readjust the voltage source for an analog OUTPUT of +0.9998V on the 1V range. Verify a change of the Digital Display from 0-9-9-9 to 1-0-0-0.

8. Calibration of Milliohm Current Source.

a). Warm-up period. With Power Switch ON, allow the instrument to warm-up for a minimum of 30 minutes.

b). Connect resistance box to inputs using four lead wires -- two connected to mΩ SOURCE (current leads) and two connected to HI and LO (voltage leads).

c). Set R box to zero resistance and read residual resistance with 164. Set R box to 10.000 ohms including residual. Adjust R1203 for reading of 10.00 in Operate position after zeroing out thermal EMF's in zero position.

FIGURE 19. Calibration Controls.

TABLE 6-3.
Voltage Range Calibration
Summary of Calibration Controls and Test Points.

Range Setting	Input Source	Source Accuracy	Analog OUTPUT Voltage	Analog OUTPUT Accuracy	Ref. Desig.	Control
100mV	100mV	±.01%	1.000V	±1mV	R520, R521	Jumper
10mV	10mV	±.01%	1.000V	±1mV	R517, R518	Jumper
1mV	1mV	±.01%	1.000V	±1mV	R514, R515	Jumper
1 V	1 V	±.01%	1.000V	±1mV	R111	1V CAL
10 V	10 V	±.01%	1.000V	±1mV	R108	10V
100 V	100 V	±.01%	1.000V	±1mV	R106	100V
1000 V	1000 V	±.01%	1.000V	±1mV	R104	1000V

TABLE 6-4.
Resistance Range Calibration
Summary of Calibration Controls and Test Points.

Range Setting	Input Source	Source Accuracy	Analog OUTPUT Voltage	Analog OUTPUT Accuracy	Ref. Desig.	Control
1KΩ	1KΩ	±.01%	1.000V	± 1mV	R738	OHMS CAL
100 Ω	100 Ω	±.02%	1.000V	± 1mV	----	None
10KΩ	10KΩ	±.02%	1.000V	± 4mV	----	None
100KΩ	100KΩ	±.02%	1.000V	± 3mV	----	None
1MΩ	1MΩ	±.02%	1.000V	± 3mV	----	None
10MΩ	10MΩ	±.4%	1.000V	± 40mV	----	None
100MΩ	100MΩ	±1%	1.000V	±100mV	----	None
1000MΩ	1000MΩ	±3%	1.000V	±500mV	----	None

TABLE 6-5.
Current Range Calibration

Range Setting	Input Source	Source Accuracy	Analog OUTPUT Voltage	Analog OUTPUT Accuracy
0.1µA	0.1µA	±.02%	1.000V	± 2mV
1µA	1µA	±.02%	1.000V	± 2mV
10µA	10µA	±.02%	1.000V	± 2mV
100µA	100µA	±.02%	1.000V	± 2mV
1mA	1mA	±.02%	1.000V	± 2mV
10mA	10mA	±.02%	1.000V	± 2mV
100mA	100mA	±.02%	1.000V	± 3mV
1000mA	1000mA	±.02%	1.000V	± 3mV
1000mA	100mA	±.02%	0.100V	±0.3mV

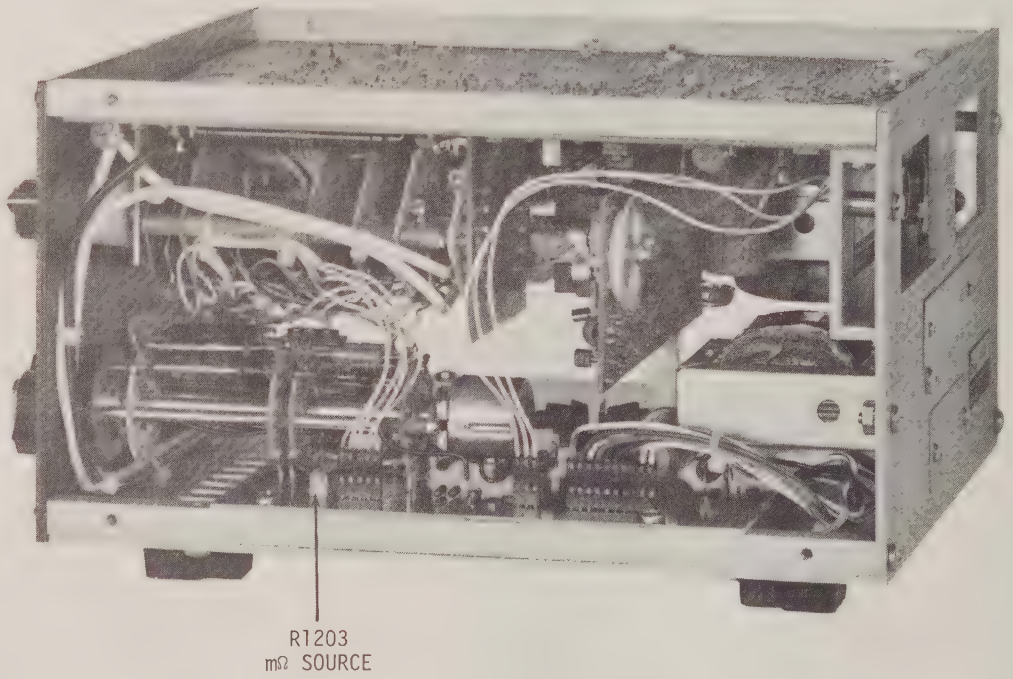


FIGURE 20. Calibration of Milliohm Current Source.

SECTION 7. REPLACEABLE PARTS

7-1. REPLACEABLE PARTS LIST. This section contains a list of components used in this instrument for user reference. The Replaceable Parts List describes the individual parts giving Circuit Designation, Description, Suggested Manufacturer (Code Number), Manufacturer Part Number, and Keithley Part Number. Also included is a Figure Reference Number where applicable. The complete name and address of the Manufacturers is listed in the CODE-TO-NAME Listing following the parts list.

TABLE 7-1.
Abbreviations and Symbols

A	ampere	F	farad	Ω	ohm
		Fig.	Figure		
CbVar	Carbon Variable			p	pico (10^{-12})
CerD	Ceramic Disc	GCb	Glass enclosed Carbon	PC	Printed Circuit
Cer Trimmer	Ceramic Trimmer			Poly	Polystyrene
Comp	Composition	k	kilo (10^{3})		
				Ref.	Reference
DCb	Deposited Carbon	μ	micro (10^{-6})		
Desig.	Designation			TCu	Tinner Copperweld
		M	Meg (10^{6})		
EAL	Electrolytic, Aluminum	Mfg.	Manufacturer	V	volt
ETB	Electrolytic, Tubular	MtF	Metal Film		
ETT	Electrolytic, tantalum	My	Mylar	W	watt
				WW	Wirewound
		No.	Number	WWVar	Wirewound Variable

7-2. ELECTRICAL SCHEMATICS AND DIAGRAMS. Schematics and diagrams are included to describe the electrical circuits as described in Section 3. Refer to Table 7-2 which identifies all schematic part numbers included.

7-3. HOW TO USE THE REPLACEABLE PARTS LIST. This Parts List is arranged such that the individual types of components are listed in alphabetical order. The parts for the instrument's Main Chassis are listed followed by printed circuit boards and other subassemblies. Refer to Table 7-3 for listing of circuit designation series assigned to each major subassembly.

7-4. HOW TO ORDER PARTS.

a. Replaceable parts may be ordered through the Sales Service Department, Keithley Instruments, Inc. or your nearest Keithley representative.

b. When ordering parts, include the following information.

1. Instrument Part Number
2. Instrument Serial Number
3. Part Description
4. Schematic Circuit Designation
5. Keithley Part Number

c. All parts listed are maintained in Keithley Spare Parts Stock. Any part not listed can be made available upon request. Parts identified by the Keithley Manufacturing Code Number 80164 should be ordered directly from Keithley Instruments, Inc.

TABLE 7-2.

Description	Circuit Designation	Schematic Part Number
Switching - Main Chassis	Front Panel	26243E
Power Supply	PC-254	26245D
Connectors	PC-254, PC-255	26246D
Analog Amplifier	PC-251	26244E
Integrator Board	PC-250	24690E
Tube Board	PC-248	24688D
Tube Board	PC-248	24689D
Milliohm Source	PC-348	24642D
Trip Circuit (Model 164TT)	PC-348	26225D
Digital Output (Model 1602)	PC-287	24685D
AC-DC Probe (Model 1601)	--	24669C

TABLE 7-3.

Circuit Desig.	Description	Connector Plug-In	Series	Page No.
--	Main Chassis	--	100	38-46
PC-254	Power Supply	--	200	38-46
PC-248	Tube Board	J802	300	38-46
PC-250	Integrator Board	J801	400	38-46
PC-254	Input Filter	--	500	38-46
PC-254	Oscillator	--	600	38-46
PC-251	Analog Amplifier	J902	700	38-46
PC-255	Connector Board	J901	800	38-46
PC-254	Connectors	--	900	38-46
PC-348	mΩ Source, Dual Trips	--	1200,1300	38-46,47

TABLE 7-4.
Mechanical Parts List

Description	Quantity Per Assembly	Keithley Part No.
1) Front Panel	1	25827C
2) Rear Panel	1	25828C
Top Cover Assembly	---	26028B
3) Cover, Sheet Metal	1	26021D
4) Screws, #6 x 3/8 slotted, pan head	4	---
Handle Assembly	---	---
5) Handle	1	HH-18
6) Screws #6-32 x 3/8" R. H. Slotted	2	---
Bottom Assembly	---	26029B
7) Bottom	1	26024C
8) Fastener	2	FA-54
Feet Assembly	---	---
9) Feet	4	24322B
10) Ball	4	FE-6
11) Screws #6 x 7/16" Phillips, Flat Head	4	---
Tilt Bail Assembly	---	---
12) Bail	1	17147B
13) Kep Nut	4	---

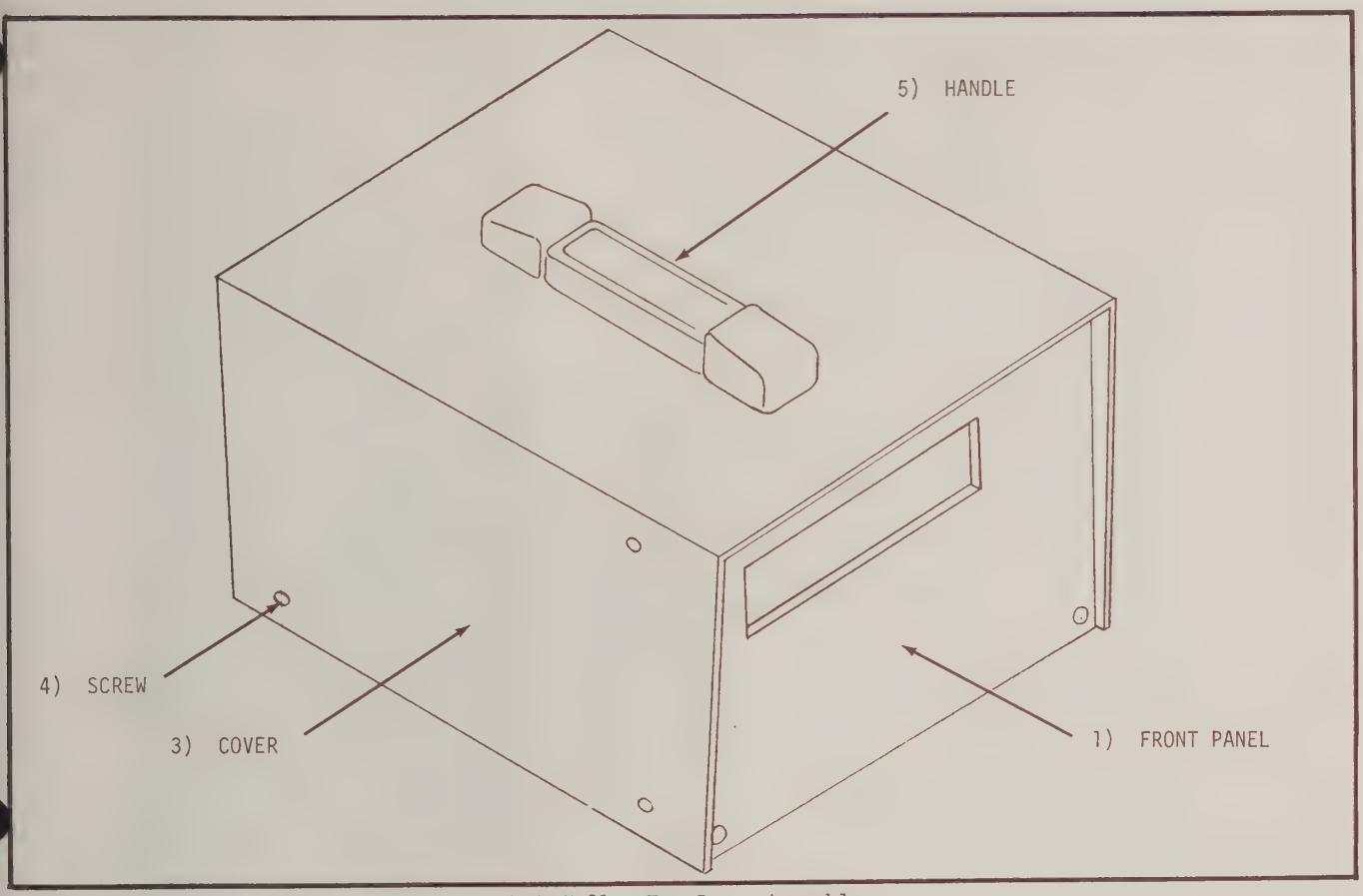


FIGURE 21. Top Cover Assembly.

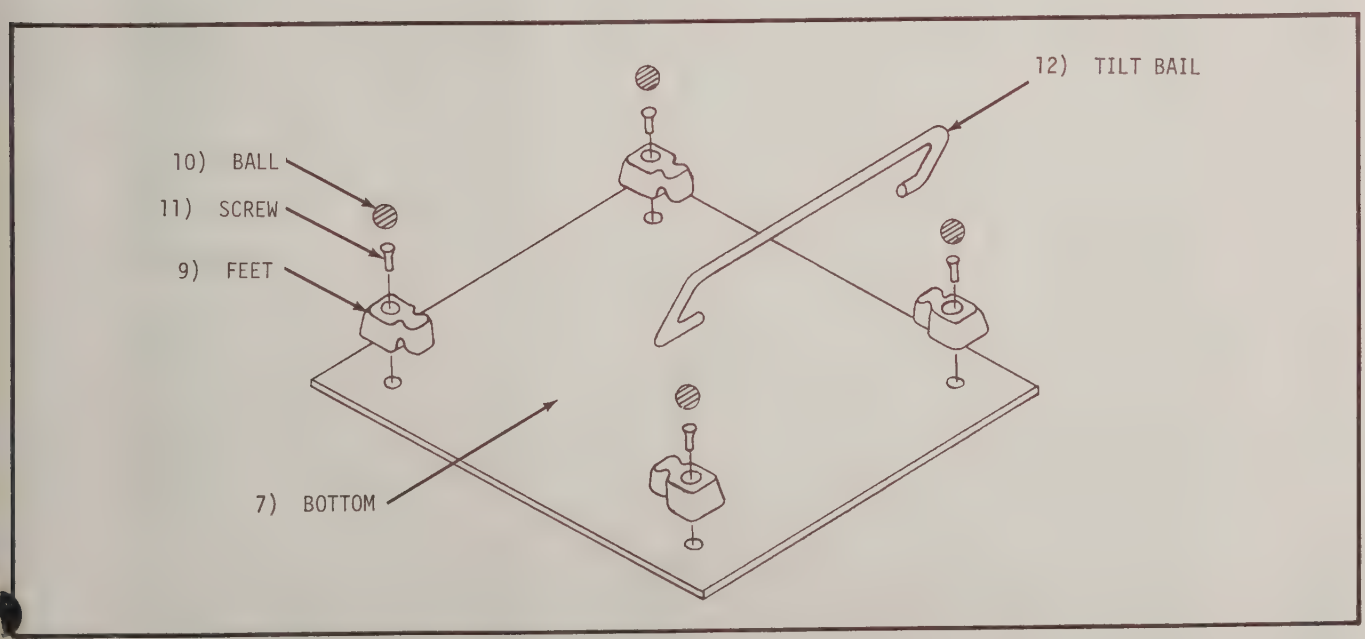


FIGURE 22. Bottom Cover Assembly.

Models 164, 164TT. (See schematics 26243E, 26245D, 26246D, 26244E, 24690E, 24688D, 24689D, 24642D).

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C101	.0047µF, 500V, CerD.	72982	801-Z5UO-472M	C22-.0047M	7
C102	.0047µF, 500V, CerD.	72982	801-Z5UO-472M	C22-.0047M	..
C103	.0047µF, 500V, CerD.	72982	801-Z5UO-472M	C22-.0047M	..
C201	2000µF, 15V, EAL	29309	3675020015C	C93-2000M	1
C202	220pF, 1000V, CerD	71590	DD-221	C64-220P	3
C203	150pF, 1000V, CerD	71590	DD-151	C64-150P	1
C204	200µF, 35V, EAL.	90201	MTV200N35	C177-200M	4
C205	200µF, 35V, EAL.	90201	MTV200N35	C177-200M	..
C206	10µF, 20V, ETT	17554	TSD1-20	C179-10M	11
C207	470pF, 1000V, CerD	71590	DD-471	C64-470P	1
C208	125µF, 15V, ETB.	73445	C426-125µF	C3-125M	2
C209	200µF, 35V, EAL.	90201	MTV200N35	C177-200M	..
C210	200µF, 35V, EAL.	90201	MTV200N35	C177-200M	..
C211	125µF, 15V, ETB.	73445	C426-125µF	C3-125M	..
C212	15µF, 300V, EAL.	90201	PTC015M300	C173-15M	1
C301	.0022µF, 500V, CerD.	72982	831-Z5UO-222M	C22-.0022M	2
C302	100pF, 1000V, CerD	71590	DD-101	C64-100P	2
C303	0.22µF, 10V, ETT	17554	TSD210226	C180-0.22M	1
C304	10pF, 1000V, CerD.	71590	DD-100	C64-10P	3
C401	10pF, 1000V, CerD.	71590	DD-100	C64-10P	..
C402	10pF, 1000V, CerD.	71590	DD-100	C64-10P	..
C403	100pF, 1000V, CerD	71590	DD-101	C64-100P	..
C404	10µF, 20V, ETT	17554	TSD1-20	C179-10M	..
C405	1.5pF, 600V, CerD.	71590	TCZ-15	C77-1.5P	1
C406	1µF, 100V, My.		MF825	C185-1M	1
C407	.001µF, 1000V, CerD.	72982	808-000-Z5R0102K	C64-.001M	1
C408	Not Used	.....	.....	.....	....
C409	220pF, 1000V, CerD	71590	DD-221	C64-220P	..
C410	10µF, 20V, ETT	17554	TSD1-20	C179-10M	..
C411	10µF, 20V, ETT	17554	TSD1-20	C179-10M	..
C412	22µF, 10V, ETT	17554	TSD2-10	C180-22M	1
C413	5pF, 1000V, CerD	71590	DD-050	C64-5P	1
C414	1µF, 50V, CerF	72982	8131050651105M	C237-1M	1
C415	.0047µF, 500V, CerD.	72982	801-Z5UO-472M	C22-.0047M	..
C416	390pF, 1000V, CerD	71590	DD-391	C64-390P	1
C417	10µF, 20V, ETT	17554	TSD1-20	C179-10M	..
C418	0.1µF, 250V, MtF	73445	C280AE	C178-.1M	3
C419	10µF, 20V, ETT	17554	TSD1-20	C179-10M	..
C420	10µF, 20V, ETT	17554	TSD1-20	C179-10M	..
C501	0.1µF, 200V, My.	13050	SM2A-.1µF	C143-.1M	2
C502	0.1µF, 200V, My.	13050	SM2A-.1µF	C143-.1M	..
C503	2µF, 100V, My.		MF1195-2µF	C188-2M	1
C601	.047µF, 200V, My	13050	SM2A-.047µF	C143-.047M	1
C602	500pF, 500V, Silver Mica	14655	CD19FD501F03	C209-500P	2
C603	500pF, 500V, Silver Mica	14655	CD19FD501F03	C209-500P	..
C604	1500pF, 500V, Silver Mica.	14655	CD19FD152F03	C209-1500P	1
C605	10µF, 20V, ETT	17554	TSD1-20	C179-10M	..
C701	Not Used	.....	.....	.....	....
C702	0.01µF, 200V, My	13050	SM1A-.01µF	C47-.01M	1
C703	10µF, 20V, ETT	17554	TSD1-20-10µF	C179-10M	..
C704	0.0047µF, 500V, CerD	72982	801-Z5UO-472M	C22-.0047M	..
C705	1.2µF, 20F, ETT.	17554	TSD1-20-1.2µF	C179-1.2M	2
C706	1.2µF, 20V, ETT.	17554	TSD1-20-1.2µF	C179-1.2M	..

Models 164, 164TT.
CAPACITORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C707	0.0047μF, 500V, CerD.	72982	801-Z5UO-472M	C22-.0047M	..
C708	220pF, 1000V, CerD.	71590	DD-221	C64-220P	..
C709	0.1μF, 250V, MtF.	73445	C280AE-.1μF	C178-.1M	..
C710	0.22μF, 250V, MtF	73445	C280AE-.22μF	C178-.22M	1
C711	0.1μF, 250V, MtF.	73445	C280AE-.1μF	C178-.1M	..
C801	0.001μF, 1000V, CerD.	72982	808000-Z5RO-102K	C64-.001M	1
C1201	470μF, 40V, EAL	Amperex	ET471X040A2	C150-470M	1
C1202	0.0022μF, 500V, CerD.	72982	831Z5UO-222M	C22-.0022M	..
C1203	0.01μF, 50V, My	84411	601PE-.01μF	C41-.01M	1

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D201	Rectifier	13327	1N4139	RF-34	2
D202	Rectifier	13327	1N4139	RF-34	..
D203	Full Wave Bridge Rectifier.	83701	PD-10	RF-36	2
D204	Rectifier	01295	1N645	RF-14	8
D205	Rectifier	01295	1N645	RF-14	..
D206	Rectifier 1A, 800V	MOT	1N4006	RF-38	1
D401	Zener, 9V, 1/2W	04713	1N936	DZ-5	3
D402	Zener, 9V, 1/2W	04713	1N936	DZ-5	..
D403	Transistor, Base-Emitter NPN, Case TO-106	07263	2N3565	TG-39	2
D404	Transistor, Base-Emitter NPN, Case TO-106	07263	2N3565	TG-39	..
D405	Rectifier	01295	1N914	RF-28	13
D406	Rectifier	01295	1N914	RF-28	..
D407	Rectifier	01295	1N914	RF-28	..
D408	Rectifier	01295	1N914	RF-28	..
D409	Rectifier	01295	1N914	RF-28	..
D410	Rectifier	01295	1N914	RF-28	..
D411	Zener, 9.1V	06751	1N713A	DZ-38	1
D412	Rectifier	01295	1N914	RF-28	..
D413	Rectifier	01295	1N914	RF-28	..
D414	Rectifier	01295	1N914	RF-28	..
D415	Rectifier	01295	1N914	RF-28	..
D416	Rectifier	01295	1N914	RF-28	..
D417	Rectifier	01295	1N914	RF-28	..
D501	Rectifier	01295	1N645	RF-14	..
D502	Rectifier	01295	1N645	RF-14	..
D601	Rectifier	01295	1N914	RF-28	..
D701	Rectifier	01295	1N645	RF-14	..
D702	Zener, 9V, 1/2W	04713	1N936	DZ-5	..
D1201	Bridge Rectifier, 2A, 100 PIV	.....	PD10	RF-36	..
D1202	Zener, 6.2V, 0.4W	06751	1N823	DZ-36	2
D1203	Zener, 6.2V, 0.4W	06751	1N823	DZ-36	..
D1204	Rectifier	01295	1N645	RF-14	..
D1205	Rectifier	01295	1N645	RF-14	..
D1206	Rectifier	01295	1N645	RF-14	..

LAMPS & FUSES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS301	Lamp, (OVERRANGE)	80164	PL-42	PL-42	1

Models 164, 164TT.
LAMPS & FUSES (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
DS302	Lamp, (POLARITY).	80164	PL-48	PL-48	1
F201	Fuse, 1/4A, 250V, 3AG, Slo-Blo.	71400	MDV-1/4A	FU-33	1
F202*	Fuse, 1/2A, 125V, 3AG, Slo-Blo.	75915	315-500	FU-35	1

*Alternate

CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J101	Binding Post, (HI) Red.	58474	DF21RC	BP-11R	1
J102	Binding Post (LO) Black	58474	DF21BC	BP-11B	1
J103	Connector, Analog Output.	02660	80PC2F	CS-32	1
J104	Binding Post, (CASE) Green.	58474	DF21GC	BP-11G	1
J201	Connector, Female, Berg				
J202	Connector, 5-pin.	22526	20052	CS-237	5
J203	Test Point.				
J204	Test Point.				
J205	Test Point.				
J801	Connector, 22-pin, card-edge type	09922	PSC4SS2212	CS-182	3
J802	Connector, 44-pin, card-edge type	09922	PSC4DD2212	CS-205	1
J901	Connector, 22-pin, card-edge type	09922	PSC4SS2212	CS-182	..
J902	Connector, 22-pin, card-edge type	09922	PSC4SS2212	CS-182	..
J903	Receptacle, 10-pin.	22526	20052	CS-237	..
J904	Receptacle, 10-pin.	22526	20052	CS-237	..
J905	Receptacle, 10-pin.	22526	20052	CS-237	..
J906	Receptacle, 10-pin.	22526	20052	CS-237	..
J1201	Housing, 10-pin	22526	20052	CS-237	..
J1202	Housing, 5-pin.	22526	20370	CS-251	..
J1203	Binding Post, (LO), Black	58474	DF21BC	BP11BLK	1
J1204	Binding Post, (HI), Red	58474	DF21RC	BP11R	1
J1205	Housing, 2-pin.			CS-261	..
J1206	Housing, 5-pin.	22526	20370	CS-251	..
J1207	Berg Pin, Female.				
J1208	Housing, 3-pin.	22526	65039034	CS-270	
J1209	Housing, 3-pin.	22526	65039034	CS-270	
J1210	Housing, 3-pin.	22526	65039034	CS-270	
P201	Receptacle, 3-pin, Line Voltage	82389	EAC301	CS-254	1
P1201	Berg Pins (10).	80164		24249A	10
P1202	Berg Pins (5)	80164		24249A	5
P1203	Not Used.	.....	.....	.....	....
P1204	Not Used.	.....	.....	.....	....
P1205	Berg Pins (2)	80164		24249A	2
P1206	Berg Pins (5)	80164		24249A	5
P1207	Berg Pin (1).	80164		24249A	1
P1208	Berg Pins (3)	80164		24249A	3
P1209	Berg Pins (3)	80164		24249A	3

TRANSISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q201	Power, NPN, Case TO-66.	02735	40312	TG-54	
Q202	NPN, Case TO-104.	02734	2N5183	TG-68	
Q203	NPN, Case TO-106.	07363	2N3565	TG-39	2
Q204	NPN, Case TO-106.	07263	2N3565	TG-39	..

Models 164, 164TT.
TRANSISTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
Q205	PNP, Case R110.	07263	S17638	TG-33	6
Q206	NPN, Case TO-5.	02734	40317	TG-43	2
Q207	PNP, Case R110.	07263	S17638	TG-33	..
Q208	NPN, Case TO-5.	02734	40319	TG-50	1
Q209	PNP, Case R110.	07263	S17638	TG-33	..
Q210	PNP, Case R110.	07263	S17638	TG-33	..
Q211	PNP, Case R110.	07263	S17638	TG-33	..
Q212	PNP, Case R110.	07263	S17638	TG-33	..
Q301	NPN, Case TO-104.	MOT	2N5551	TG-67	3
Q302	NPN, Case TO-5.	02735	40346	TG-44	2
Q303	NPN, Case TO-5.	02735	40346	TG-44	..
Q304	NPN, Case TO-106.	07263	2N5134	TG-65	6
Q305	NPN, Case TO-104.	MOT	2N5551	TG-67	..
Q306	NPN, Case TO-104.	MOT	2N5551	TG-67	..
Q401	N-Chan, Fet	04713	2N4220	TG-42	4
Q402	FET, Case TO-92	01295	T1S70	TG-71	2
Q403	FET, Case TO-92	01295	T1S70	TG-71	..
Q404	PNP, Case TO-106.	07263	2N5139	TG-66	3
Q405	NPN, Case TO-106.	07263	2N5134	TG-65	..
Q406	Not Used.	.....	.....	.....	....
Q407	Not Used.	.....	.....	.....	....
Q408	N-Chan, FET	04713	2N4220	TG-42	..
Q409	PNP, Case TO-106.	07263	2N5139	TG-66	..
Q410	NPN, Case TO-106.	07263	2N5134	TG-65	..
Q411	N-Chan, FET	04713	2N4220	TG-42	..
Q412	NPN, Case TO-106.	07263	2N5134	TG-65	..
Q413	PNP, Case TO-106.	07263	2N5139	TG-66	..
Q414	NPN, Case TO-106.	07263	2N5134	TG-65	..
Q415	PNP, Case TO-106.	07263	2N5139	TG-66	..
Q416	NPN, Case TO-106.	07263	2N5134	TG-65	..
Q601	NPN, Case TO-92	04713	2N5089	TG-62	6
Q602	NPN, Case TO-92	04713	2N5089	TG-62	..
Q603	NPN, Case TO-92	04713	2N5089	TG-62	..
Q701	N-Chan FET (Selected*).	94145	RN1030	TG-51 (24598A)*	2
Q702	N-Chan FET (Selected*).	94145	RN1030	TG-51 (24598A)*	..
Q703	NPN, Case TO-92 (Selected*)	04713	2N5089*	TG-62 (24219A)*	..
Q704	PNP, Case TO-92	04713	2N5087	TG-61	2
Q705	N-Chan FET.	04713	MPF-103	TG-41	1
Q706	NPN, Case TO-92	04713	2N5089	TG-62	..
Q707	NPN, Case TO-92	04713	2N5089	TG-62	..
Q708	PNP, Case TO-92	04713	2N5087	TG-61	..
Q1201	Transistor.	07263	40317	TG-43	..

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA201	Regulator, 10-pin Case TO-100	07263	U5R772-339	IC-14	1
QA301	Dual J-K Flip-Flop, 14-pin DIP.	04713	MC891P	IC-9	4
QA302	Dual J-K Flip-Flop, 14-pin DIP.	04713	MC891P	IC-9	..
QA303	Quad 2-input NOR, 14-pin DIP.	04713	MC824P	IC-5	3
QA304	Quad 2-input NOR, 14-pin DIP.	04713	MC824P	IC-5	..
QA305	Hex Inverters, 14-pin DIP	04713	MC889P	IC-7	1
QA306	Dual J-K Flip-Flop, 14-pin DIP.	04713	MC891P	IC-9	..
QA307	Dual J-K Flip-Flop, 14-pin DIP.	04713	MC891P	IC-9	..
QA308	Decade Counter, 14-pin DIP.	04713	MC880P	IC-17	3
QA309	Decade Counter, 14-pin DIP.	04713	MC880P	IC-17	..

Models 164, 164TT.
INTEGRATED CIRCUITS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA310	Decade Counter, 14-pin DIP	04713	MC880P	IC-17	..
QA311	Quad Latch, 16-pin DIP	04713	MC867P	IC-16	3
QA312	Quad Latch, 16-pin DIP	04713	MC867P	IC-16	..
QA313	Quad Latch, 16-pin DIP	04713	MC867P	IC-16	..
QA314	Decoder/driver, 16-pin DIP	07263	UGB996079X	IC-3	3
QA315	Decoder/driver, 16-pin DIP	07263	UGB996079X	IC-3	..
QA316	Decoder/driver, 16-pin DIP	07263	UGB996079X	IC-3	..
QA401	Amplifier, 8-pin, Case TO-99	07263	U5B770939X	IC-1	3
QA402	Amplifier, 8-pin, Case TO-99	07263	U5B770939X	IC-1	..
QA403	Diff. Comparator, 8-pin, Case TO-99.	07263	U5B771039X	IC-4	1
QA404	Quad 2-input, NAND, 14-pin DIP	04713	MC824P	IC-5	..
QA701	Dual J-K Flip-Flop, 14-pin DIP	04713	MC890P	IC-8	1
QA702	Amplifier, 8-pin, Case TO-99	07263	U5B770939X	IC-1	..
QA703	Amplifier, 8-pin, Case TO-99	12040	LM301AH	IC-2	2
QA704	Amplifier, 8-pin, Case TO-99	12040	LM301AH	IC-2	..
QA801	Binary Counter, 14-pin DIP	04713	MC-877P	IC-21	1
QA1201	Regulator, Case TO-220	04713	MC7815CP	IC-96	1
QA1202	Amplifier, 8-pin, Case TO-99	12040	LM308H	IC-67	1

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R101	10MΩ, 1%, 1/2W, MtF.	07716	MEH-10MΩ	R170-10M	1
R102	200kΩ, 1%, 1/2W, MtF	07716	MEH-200KΩ	R94-200K	1
R103	1kΩ, 0.1%, 1/2W, MtF	91637	MFF-1KΩ	R169-1K	2
R104	50Ω, 20%, 2W, WW	71450	1NS-115-50Ω	RP50-50	1
R105	10kΩ, 0.1%, 1/2W, MtF.	91637	MFF-10K	R169-10K	2
R106	500Ω, 20%, 2W, WW.	71450	1NS-115-500Ω	RP50-500	1
R107	100kΩ, 0.1%, 1/2W, MtF	91637	MFF-100KΩ	R169-100K	2
R108	5kΩ, 20%, 2W, WW	71450	1NS-115-5KΩ	RP50-5K	2
R109	1MΩ, 0.1%, 1/2W, MtF	91637	MFF-1MΩ	R169-1M	2
R110	100kΩ, 1%, 1/8W, MtF	07716	CEA-100KΩ-1%	R88-100K	4
R111	50kΩ, 20%, 1.75W, Cermet	73138	77PR-50KΩ	RP64-50K	1
R112	10^7Ω, 1%, 1W, DCb.	91637	DC-1-10^7Ω	R13-10^7	1
R113	10^9Ω, 20%, 1/2W, Comp.	75042	GBT-10^8Ω	R37-10^9	2
R114	10^8Ω, 1%, 2W, DCb.	91637	DC-2-10^8Ω	R14-10^8	1
R115	1MΩ, 0.1%, 1/2W, MtF	91637	MFF-1MΩ	R169-1M	..
R116	100kΩ, 0.1%, 1/2W, MtF	91637	MFF-100KΩ	R169-100K	..
R117	10kΩ, 0.1%, 1/2W, MtF.	91637	MFF-10KΩ	R169-10K	..
R118	1kΩ, 0.1%, 1/2W, MtF	91637	MFF-1KΩ	R169-1K	..
R119	99.9Ω, 0.1%, 1/2W, MtF	91637	MFF-99.9Ω	R169-99.9	1
R120	0.1Ω, 0.1%, 5W, WW	02985	TS-5W-.1Ω	R167-.1	1
R121	1Ω, 0.1%, 1/4W, WW	01686	7009-1Ω	R95-1	1
R122	10Ω, 0.1%, 1/4W, WW.	01686	7009-10Ω	R95-10	1
R123	220Ω, 10%, 1/4W, Comp.	01121	CB-221-10%	R76-220	1
R201	6.8kΩ, 10%, 1/4W, Comp	01121	CB-682-10%	R76-6.8K	1
R202	0.2Ω, 10%, TCu	91637	CW-2-.2Ω	R151-0.2	1
R203	10kΩ, 1%, 1/8W, MtF.	07716	CEA-10K-1%	R88-10K	3
R204	2.49kΩ, 1%, 1/8W, MtF.	07716	CEA-2.49K-1%	R88-2.49K	1
R205	1kΩ, 10%, 1/4W, Comp	01121	CB-102-10%	R76-1K	5
R206	3Ω, 1%, 1/2W, DCb.	91637	DCF-1/2-3Ω	R12-3	2
R207	1.8kΩ, 10%, 1/4W, Comp	01121	CB-182-10%	R76-1.8K	1
R208	3.32kΩ, 1%, 1/8W, MtF.	07716	CEA-3.32K-1%	R88-3.32K	1
R209	1kΩ, 20%, 2W, WW	71450	1NS-115-1K	RP50-1K	1
R210	3.01kΩ, 1%, 1/8W, MtF.	07716	CEA-3.01K-1%	R88-3.01K	3
R211	15kΩ, 10%, 1/4W, Comp.	01121	CB-153-10%	R76-15K	1
R212	7.5kΩ, 1%, 1/8W, MtF	07716	CEA-7.5K-1%	R88-7.5K	8

Models 164, 164TT.
RESISTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R213	10Ω, 10%, 1/2W, Comp	01121	EB-100-10%	R1-10	1
R214	33kΩ, 10%, 1/4W, Comp.	01121	CB-333-10%	R76-33K	8
R215	3Ω, 1%, 1/2W, DCb.	91637	DCF-1/2-3Ω	R12-3	..
R216	33kΩ, 10%, 1/4W, Comp.	01121	CB-333-10%	R76-33K	..
R217	33kΩ, 10%, 1/4W, Comp.	01121	CB-333-10%	R76-33K-10%	..
R218	7.5kΩ, 1%, 1/8W, MtF	07716	CEA-7.5K-1%	R88-7.5K-1%	..
R219	82Ω, 10%, 1/2W, Comp	01121	EB-82R-10%	R1-82	1
R220	1MΩ, 10%, 1/4W, Comp	01121	CB-105-10%	R76-1M	2
R301	100kΩ, 10%, 1W, Comp	01121	GB-104-10%	R2-100K	1
R302	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	9
R303	3.3kΩ, 10%, 1/4W, Comp	01121	CB-332-10%	R76-3.3K	2
R304	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	..
R305	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	..
R306	100kΩ, 10%, 1/2W, Comp	01121	EB-104-10%	R1-100K	1
R307	47kΩ, 10%, 1/4W, Comp.	01121	CB-473-10%	R76-47K	3
R308	Not Used	.....	.....	.....	....
R309	80.6kΩ, 1%, 1/2W, MtF.	07716	CEC-80.6K-1%	R94-80.6K	1
R310	7.87kΩ, 1%, 1/8W, MtF.	07716	CEA-7.8K-1%	R88-7.87K	1
R311	1kΩ, 10%, 1/4W, Comp	01121	CB-102-10%	R76-1K	..
R312	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	..
R313	10kΩ, 1%, 1/2W, MtF.	07716	CEC-10K-1%	R94-10K	3
R314	10kΩ, 1%, 1/2W, MtF.	07716	CEC-10K-1%	R94-10K	..
R315	10kΩ, 1%, 1/2W, MtF.	07716	CEC-10K-1%	R94-10K	..
R401	10kΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	6
R402	10kΩ, 20%, Cermet.	73138	77PR-10KΩ	RP64-10K	2
R403	7.5kΩ, 1%, 1/8W, MtF	07716	CEA-7.5KΩ-1%	R88-7.5K	..
R404	7.5kΩ, 1%, 1/8W, MtF	07716	CEA-7.5KΩ-1%	R88-7.5K	..
R405	7.5kΩ, 1%, 1/8W, MtF	07716	CEA-7.5KΩ-1%	R88-7.5K	..
R406	Selected*Ω, 1%, 1/8W, MtF.	91637	MFF-1/8-*	R177*	..
R407	10kΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	..
R408	10kΩ, 20%, Cermet.	73138	77PR10KΩ	RP64-10K	..
R409	7.5kΩ, 1%, 1/8W, MtF	07716	CEA-7.5KΩ-1%	R88-7.5K	..
R410	7.5kΩ, 1%, 1/8W, MtF	07716	CEA-7.5KΩ-1%	R88-7.5K	..
R411	7.5kΩ, 1%, 1/8W, MtF	07716	CEA-7.5KΩ-1%	R88-7.5K	..
R412	Selected*Ω, 1%, 1/8W, MtF.	91637	MFF-1/8-*	R177-*	..
R413	49.9kΩ, 1%, 1/8W, MtF.	91637	MFF-1/8-49.9K	R177-49.9K	2
R414	49.9kΩ, 1%, 1/8W, MtF.	91637	MFF-1/8-49.9K	R177-49.9K	..
R415	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	6
R416	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R417	1kΩ, 10%, 1/4W, Comp	01121	CB-102-10%	R76-1K	..
R418	301kΩ, 1%, 1/8W, MtF	07716	CEA-301K-1%	R88-301K	2
R419	301kΩ, 1%, 1/8W, MtF	07716	CEA-301K-1%	R88-301K	..
R420	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	..
R421	680Ω, 10%, 1/4W, Comp.	01121	CB-681-10%	R76-680	3
R422	33kΩ, 10%, 1/4W, Comp.	01121	CB-333-10%	R76-33K	..
R423	4.7kΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-4.7K	4
R424	4.7kΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-4.7K	..
R425	Not Used	.....	.....	.....	....
R426	Not Used	.....	.....	.....	....
R427	Not Used	.....	.....	.....	....
R428	680Ω, 10%, 1/4W, Comp.	01121	CB-681-10%	R76-680	..
R429	4.7kΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-4.7K	..
R430	33kΩ, 10%, 1/4W, Comp.	01121	CB-333-10%	R76-33K	..
R431	4.7kΩ, 10%, 1/4W, Comp	01121	CB-472-10%	R76-4.7K-10%	..
R432	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R433	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R434	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R435	47Ω, 10%, 1/4W, Comp	01121	CB-47R-10%	R76-47	4
R436	47Ω, 10%, 1/4W, Comp	01121	CB-47R-10%	R76-47	..
R437	2.2kΩ, 10%, 1/4W, Comp	01121	CB-222-10%	R76-2.2K	3
R438	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	..

Models 164, 164TT.
RESISTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R439	47Ω, 10%, 1/4W, Comp	01121	CB-47R-10%	R76-47	..
R440	47Ω, 10%, 1/4W, Comp	01121	CB-47R-10%	R76-47	..
R441	8.87kΩ, 1%, 1/8W, MtF.	07716	CEA-8.87K-1%	R88-8.87K	1
R442	3.01kΩ, 1%, 1/8W, MtF.	07716	CEA-3.01K-1%	R88-3.01K	..
R443	2.2kΩ, 10%, 1/4W, Comp	01121	CB-222-10%	R76-2.2K	..
R444	2.49kΩ, 1%, 1/8W, MtF.	07716	CEA-2.49K-1%	R88-2.49K	1
R445	10kΩ, 1%, 1/8W, MtF.	07716	CEA-10K-1%	R88-10K	..
R446	2.2kΩ, 10%, 1/4W, Comp	01121	CB-222-10%	R76-2.2K	..
R447	237Ω, 1%, 1/8W, MtF.	07716	CEA-237-1%	R88-237	2
R448	56kΩ, 10%, 1/4W, Comp.	01121	CB-563-10%	R76-56K	2
R449	1kΩ, 1%, 1/8W, MtF	07716	CEA-1K-1%	R88-1K	2
R450	4.99kΩ, 1%, 1/8W, MtF.	07716	CEA-4.99K-1%	R88-4.99K	2
R451	27kΩ, 10%, 1/4W, Comp.	01121	CB-273-10%	R76-27K	1
R452	82kΩ, 10%, 1/4W, Comp.	01121	CB-823-10%	R76-82K	1
R453	33kΩ, 10%, 1/4W, Comp.	01121	CB-333-10%	R76-33K	..
R454	680Ω, 10%, 1/4W, Comp.	01121	CB-681-10%	R76-680	..
R455	237Ω, 1%, 1/8W, MtF.	07716	CEA-237-1%	R88-237	..
R456	56kΩ, 10%, 1/4W, Comp.	01121	CB-563-10%	R76-56K	..
R457	4.99kΩ, 1%, 1/8W, MtF.	07716	CEA-4.99K-1%	R88-4.99K	..
R458	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R501	150kΩ, 10%, 1/2W, Comp	01121	EB-150K-10%	R1-150K	1
R502	10kΩ, 10%, 1/2W, Comp.	01121	EB-10K-10%	R1-10K	1
R503	1MΩ, 1%, 1/8W, MtF	07716	CEA-1MΩ-1%	R88-1M	1
R504	49.9kΩ, 1%, 1/8W, MtF.	07716	CEA-49.9K-1%	R88-49.9K	2
R505	100kΩ, 20%, Cermet	73138	77PR-100K	RP64-100K	1
R506	49.9kΩ, 1%, 1/8W, MtF.	07716	CEA-49.9K-1%	R88-49.9K	..
R507	Not Used	.....	.....	.....	..
R508	1.5kΩ, 1%, 1/8W, MtF	07716	CEA-1.5K-1%	R88-1.5K	2
R509	1.5kΩ, 1%, 1/8W, MtF	07716	CEA-1.5K-1%	R88-1.5K	..
R510	10MΩ, 10%, 1/4W, Comp.	01121	CB-106-10%	R76-10M	1
R511	10^8Ω, 20%, 1/2W, Comp.	75042	GBT-10^8Ω	R37-10^8	1
R512	10^9Ω, 20%, 1/2W, Comp.	75042	GBT-10^9Ω	R37-10^9	..
R513	89.9kΩ, 0.1%, 1/2W, MtF.	91637	MFF-89.9K	R169-89.9K	1
R514	100Ω, 1%, 1/8W, MtF.	07716	CEA-100-1%	R88-100	3
R515	100Ω, 1%, 1/8W, MtF.	07716	CEA-100-1%	R88-100	..
R516	8.99kΩ, 0.1%, 1/2W, MtF.	91637	MFF-8.99K	R169-8.99K	1
R517	10Ω, 10%, 1/4W, Comp	01121	CB-10R-10%	R76-10	2
R518	10Ω, 10%, 1/4W, Comp	01121	CB-10R-10%	R76-10	..
R519	899Ω, 0.1%, 1/2W, MtF.	91637	MFF-899	R169-899	1
R520	1Ω, 1%, 1/2W, DCb.	91637	DCF-1/2-1Ω	R12-1	2
R521	1Ω, 1%, 1/2W, DCb.	91637	DCF-1/2-1Ω	R12-1	..
R601	3.01kΩ, 1%, 1/8W, MtF.	07716	CEA-3.01K-1%	R88-3.01K	..
R602	113kΩ, 1%, 1/8W, MtF	07716	CEA-113K-1%	R88-113K	1
R603	100Ω, 1%, 1/8W, MtF.	07716	CEA-100-1%	R88-100	..
R604	6.98kΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-6.98K	R168-6.98K	1
R605	5kΩ, 20%, 2W, WW	71450	1NS-115-5K	RP50-5K	..
R606	32.4kΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-32.4K	R168-32.4K	2
R607	32.4kΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-32.4K	R168-32.4K	..
R608	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	..
R609	3.9kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-3.9K	1
R610	47Ω, 10%, 1/4W, Comp	01121	CB-152-10%	R76-47	1
R611	10kΩ, 1%, 1/8W, MtF.	07716	CEA-10K-1%	R88-10K	..
R701	47kΩ, 10%, 1/4W, Comp.	01121	CB-473-10%	R76-47K	..
R702	1kΩ, 10%, 1/4W, Comp	01121	CB-102-10%	R76-1K	..
R703	100Ω, 0.05%, 1/4W, WW.	17870	1352-100Ω	R157-100	1
R704	1MΩ, 10%, 1/4W, Comp	01121	CB-105-10%	R76-1M	..
R705	1kΩ, 10%, 1/4W, Comp	01121	CB-102-10%	R76-1K	..
R706	100kΩ, 1%, 1/8W, MtF	07716	CEA-100K-1%	R88-100K	..
R707	10kΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	..
R708	33kΩ, 10%, 1/4W, Comp.	01121	CB-333-10%	R76-33K	..

Models 164, 164TT.
RESISTORS (Cont'd)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R709	3.3kΩ, 10%, 1/4W, Comp	01121	CB-332-10%	R76-3.3K	..
R710	10kΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	..
R711	1MΩ, 10%, 1/4W, Comp	01121	CB-105-10%	R76-1M	1
R712	10kΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	..
R713	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	..
R714	470kΩ, 10%, 1/4W, Comp	01121	CB-474-10%	R76-470K	1
R715	33kΩ, 10%, 1/4W, Comp.	01121	CB-333-10%	R76-33K	..
R716	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R717	56kΩ, 10%, 1/4W, Comp.	01121	CB-563-10%	R76-56K	1
R718	47kΩ, 10%, 1/4W, Comp.	01121	CB-473-10%	R76-47K	..
R719	68kΩ, 10%, 1/4W, Comp.	01121	CB-683-10%	R76-68K	2
R720	680Ω, 10%, 1/4W, Comp.	01121	CB-681-10%	R76-680	2
R721	680Ω, 10%, 1/4W, Comp.	01121	CB-681-10%	R76-680	..
R722	500Ω, 1/4W, Carbon	76055	MTC52L1-500Ω	RP59-500	1
R723	68kΩ, 10%, 1/4W, Comp.	01121	CB-683-10%	R76-68K	..
R724	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R725	47Ω, 10%, 1/4W, Comp	01121	CB-47R-10%	R76-47	2
R726	470Ω, 10%, 1/4W, Comp.	01121	CB-471-10%	R76-470	2
R727	4.75kΩ, 1%, 1/8W, MtF.	07716	CEA-4.75K-1%	R88-4.75K	2
R728	49.9kΩ, 1%, 1/8W, MtF.	07716	CEA-49.9K-1%	R88-49.9K	2
R729	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R730	1kΩ, 1%, 1/8W, MtF	07716	CEA-1K-1%	R88-1K	..
R731	4.75kΩ, 1%, 1/8W, MtF.	07716	CEA-4.75K-1%	R88-4.75K	..
R732	10kΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	..
R733	50kΩ, 20%, 0.75W, Cermet	73138	77PR-50KΩ	RP64-50K	1
R734	49.9kΩ, 1%, 1/8W, MtF.	07716	CEA-49.9K-1%	R88-49.9K	..
R735	100kΩ, 1%, 1/8W, MtF	07716	CEA-100K-1%	R88-100K	..
R736	100kΩ, 10%, 1/4W, Comp	01121	CB-104-10%	R76-100K	..
R737	1kΩ, 1%, 1/8W, MtF	07716	CEA-1K-1%	R88-1K	..
R738	2kΩ, 20%, 0.75W, Cermet.	73138	77PR-2K	RP64-2K	1
R739	8.06kΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-8.06K	R168-8.06K	1
R740	9.9kΩ, 0.1%, 1/8W, MtF	91637	MFF-1/8-9.9K	R168-9.9K	1
R741	100Ω, 0.1%, 1/8W, MtF.	91637	MFF-1/8-100	R168-100	1
R742	10kΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-10K	R168-10K	3
R743	10kΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-10K	R168-10K	..
R744	Not Used	.....	.....	.....	....
R745	10kΩ, 0.1%, 1/8W, MtF.	91637	MFF-1/8-10K	R168-10K	..
R746	1.5kΩ, 10%, 1/4W, Comp	01121	CB-152-10%	R76-1.5K	..
R747	47Ω, 10%, 1/4W, Comp	01121	CB-47R-10%	R76-47	..
R748	470Ω, 10%, 1/4W, Comp.	01121	CB-471-10%	R76-470	..
R801	10kΩ, 10%, 1/4W, Comp.	01121	CB-103-10%	R76-10K	..
R1201	25Ω, 5%, 5W, WW.	91637	RS-5-25Ω	R4A-25	1
R1202	806Ω, 1%, 1/2W, MtF.	07716	CEC-806-1%	R94-806	1
R1203	500Ω, 0.75W, Cermet.	73138	77PR-500	RP64-500	1
R1204	4.02kΩ, 1%, 1/2W, MtF.	07716	CEC-4020-1%	R94-4020	1
R1205	100Ω, 0.1%, 10W, WW.	02985	TS-10W-100	R221-100	1
R1206	1kΩ, 0.1%, 1W.	01686	7040-1K	R70-1K	1
R1207	10kΩ, 0.1%, 1W	DLE	MFF-10K	R169-10K	1
R1208	100kΩ, 0.02%, 1W, WW	DLE	MFF-100K	R169-100K	1
R1209	1MΩ, 0.1%, 1W.	DLE	MFF-1M	R169-1M	1
R1210	0.12Ω, 5%, 2W, WW.	75042	BWH-2W-.12Ω	R201-.12	1
R1211	1.8Ω, 5%, 2W, WW	75042	BWH-2W-1.8Ω	R201-1.8	1
R1212	20Ω, 1%, 1/2W, MtF	07716	CEC-20-1%	R94-20	1
R1213	200Ω, 1%, 1/2W, MtF.	07716	CEC-200-1%	R94-200	1
R1214	2kΩ, 1%, 1/2W, MtF	07716	CEC-2K-1%	R94-2K	1
R1215	50kΩ, 20%, 2W, Cermet.	71450	550-50KΩ	RP74-50K	1
R1216	3.33MΩ, 1%, 1/2W, DCb.	91637	DCF-1/2-3.33M	R12-3.33M	1
R1217	2.2kΩ, 10%, 1/2W, Comp	01121	EB-2.2KΩ-10%	R1-2.2K	1
R1218	226Ω, 1%, 1/2W, MtF.	07716	CEC-226-1%	R94-226	1

Models 164, 164TT.
MISCELLANEOUS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
S101	Switch, Rotary (RANGE)	80164	SW-319A	SW-319A	1
S201	Not Used	.....	.....	.....	....
S202	Switch	80164	SW-318	SW-318	1
S1201	Mode Switch, Rotary.	80164	SW-372	SW-372	1
S1202	Source Switch, Toggle.	80164	SW-197	SW-197	1
T201	Transformer.	80164	TR-130	TR-130	1
T1201	Transformer.	80164	TR-138	TR-138	1
V301	Tube, Readout.	80164	EV-841	EV-841	3
V302	Tube, Readout.	80164	EV-841	EV-841	..
V303	Tube, Readout.	80164	EV-841	EV-841	..

Model 164TT Version Only.
(See schematic 26225D)

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C1301	Capacitor, 470pF, 500V, CerD.	56289	.....	C22-470P	2
C1302	Capacitor, 470pF, 500V, CerD.	56289	.....	C22-470P	..
D1301	Diode, zener, 6.2V, 0.4W.	06751	1N823	DZ-36	1
D1302	Diode	01295	1N645	RF-14	2
D1303	Diode	01295	1N645	RF-14	..
DS1301	Pilot Lamp, LO LIMIT.	07137	RBL41A1344	PL-45	2
DS1302	Pilot Lamp, HI LIMIT.	07137	RBL41A1344	PL-45	..
J907	Connector, Housing, 10-pin.	22526	20052	CS-237	
J1301	Connector, Housing, 3-pin	22526	65039034	CS-270	
J1302	Connector, Housing, 3-pin	22526	65039034	CS-270	
J1303	Connector, Housing, 5-pin	22526	20370	CS-251	
J1304	Connector, Housing, 5-pin	22526	20370	CS-251	
J1305	Connector, Housing, 5-pin	22526	20370	CS-251	
K1301	Relay, Form A (SPST-NO)	23020	191-TE1A1-5S	RL-44	2
K1302	Relay, Form A (SPST-NO)	23020	191-TE1A1-5S	RF-44	
P1301	Connector, Berg Pins (3).	80164	.....	24249A	3
P1302	Connector, Berg Pins (3).	80164	.....	24249A	3
P1303	Connector, Berg Pins (5).	80164	.....	24249A	5
P1304	Connector, Berg Pins (5).	80164	.....	24249A	5
P1305	Connector, Berg Pins (5).	80164	.....	24249A	5
Q1301	Transistor, NPN, Case TO-92	04713	2N3903	TG-49	1
Q1302	Transistor, PNP, Case TO-92	04713	2N3905	TG-53	1
QA1301	Integrated Circuit, 8-pin DIP	07263	UGT7741393	IC-42	2
QA1302	Integrated Circuit, 8-pin DIP	07263	UGT7741393	IC-42	..
R1301	1kΩ, 1%, 1/2W, MtF.	07716	CEC-1k-1%	R94-1K	2
R1302	200Ω, 1%, 1/2W, MtF	07716	CEC-200-1%	R94-200	2
R1303	200Ω, 1%, 1/2W, MtF	07716	CEC-200-1%	R94-200	..
R1304	1kΩ, 1%, 1/2W, MtF.	07716	CEC-1K-1%	R94-1K	..
R1305	2.74kΩ, 1%, 1/2W, MtF	07716	CEC-2.74K-1%	R94-2.74K	2
R1306	2.74kΩ, 1%, 1/2W, MtF	07716	CEC-2.74K-1%	R94-2.74K	..
R1307	2kΩ, 0.75W, Var	73138	78LR2K56BW	RP95-2K	2
R1308	2kΩ, 0.75W, Var	73138	78LR2K56BW	RP95-2K	..
R1309	10kΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	4
R1310	10kΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	..
R1311	4.7kΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	2
R1312	10MΩ, 10%, 1/4W, Comp	01121	CB-106-10%	R76-10M	2
R1313	680Ω, 10%, 1/4W, Comp	01121	CB-681-10%	R76-680	2
R1314	10kΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	..
R1315	10kΩ, 10%, 1/4W, Comp	01121	CB-103-10%	R76-10K	..
R1316	4.7kΩ, 10%, 1/4W, Comp.	01121	CB-472-10%	R76-4.7K	..
R1317	10MΩ, 10%, 1/4W, Comp	01121	CB-106-10%	R76-10M	..
R1318	680Ω, 10%, 1/4W, Comp	01121	CB-681-10%	R76-680	..
R1319	120Ω, 10%, 1/4W, Comp	01121	CB-121-10%	R76-120	2
R1320	120Ω, 10%, 1/4W, Comp	01121	CB-121-10%	R76-120	..
S1301	Switch, Pushbutton (See DS1301)	.....	.....	.....	....
S1302	Switch, Pushbutton (See DS1302)	.....	.....	.....	....
TB1301	Terminal Board.				

Model 1602 Digital Output, PC-287.
(See schematic 24685D)

CAPACITORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
C1001	1.2µF, 20V, ETT	17554	TSD1-20	C179-1.2M	1
C1002	.001µF, 1000V, CerD	72982	801000X5F0102K	C22-.001M	1
C1003	.0022µF, 1000V, CerD.	72982	811000X5F0222K	C22-.0022M	1

CONNECTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
J1001	Receptacle, 10-Pin.	22526	20052	CS-237	3
J1002	Receptacle, 10-Pin.	22526	20052	CS-237	..
J1003	Receptacle, 10-Pin.	22526	20052	CS-237	..
J1004	Receptacle, 22-Pin.	09922	PSC4SS2212	CS-182	1
J1005	Receptacle, 44-Pin.	09922	PSC4DD2212	CS-205	1
J1006	Receptacle, 50-Pin.	02660	57405001	CS-221	1
	Plug, Mate of J1006 (Not Supplied).	02660	57305001	CS-220	1

DIODES

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
D1001	Germanium	15238	1N3592	RF-39	5
D1002	Germanium	15238	1N3592	RF-39	..
D1003	Germanium	15238	1N3592	RF-39	..
D1004	Germanium	15238	1N3592	RF-39	..
D1005	Germanium	15238	1N3592	RF-39	..
D1006	Silicon	01295	1N914	RF-28	7
D1007	Silicon	01295	1N914	RF-28	..
D1008	Silicon	01295	1N914	RF-28	..
D1009	Silicon	01295	1N914	RF-28	..
D1010	Silicon	01295	1N914	RF-28	..
D1011	Silicon	01295	1N914	RF-28	..
D1012	Silicon	01295	1N914	RF-28	..

INTEGRATED CIRCUITS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
QA1001	Quad, NAND Gate, 14-pin DIP, TO-116	04713	MC858P	IC-22	6
QA1002	Quad, NAND Gate, 14-pin DIP, TO-116	04713	MC858P	IC-22	..
QA1003	Quad, NAND Gate, 14-pin DIP, TO-116	04713	MC858P	IC-22	..
QA1004	Quad, NAND Gate, 14-pin DIP, TO-116	04713	MC858P	IC-22	..
QA1005	Inverter-Flip-Flop, 14-pin DIP, TO-116.	04713	MC887P	IC-23	1
QA1006	Quad, NAND Gate, 14-pin DIP, TO-116	04713	MC858P	IC-22	..
QA1007	Quad, NAND Gate, 14-pin DIP, TO-116	04713	MC858P	IC-22	..
QA1008	Binary Counter, 14-pin DIP, TO-116.	04713	MC877P	IC-21	1

Model 1602 Digital Output, PC-287.
(See schematic 24685D)

RESISTORS

Circuit Desig.	Description	Mfr. Code	Mfr. Desig.	Keithley Part No.	Qty.
R1001	3.3kΩ, 10%, 1/4W, Comp.	44655	RC07-332-10%	R76-3.3K	3
R1002	1.5kΩ, 10%, 1/4W, Comp.	44655	RC07-152-10%	R76-1.5K	2
R1003	1.5kΩ, 10%, 1/4W, Comp.	44655	RC07-152-10%	R76-1.5K	..
R1004	3.3kΩ, 10%, 1/4W, Comp.	44655	RC07-332-10%	R76-3.3K	..
R1005	1.5kΩ, 10%, 1/4W, Comp.	44655	RC07-152-10%	R76-3.3K	..
R1006	1kΩ, 10%, 1/4W, Comp.	44655	RC07-102-10%	R76-1K	1
R1007	560kΩ, 10%, 1/4W, Comp.	44655	RC07-561-10%	R76-560	1
R1008	10kΩ, 10%, 1/8W, Comp	01121	BB-103-10%	R143-10K	2
R1009	10kΩ, 10%, 1/8W, Comp	01121	BB-103-10%	R143-10K	..
R1010	100kΩ, 10%, 1/4W, Comp.	44655	RC07-104-10%	R76-100K	2
R1011	27kΩ, 10%, 1/4W, Comp	44655	RC07-273-10%	R76-27K	2
R1012	15kΩ, 10%, 1/4W, Comp	44655	RC07-153-10%	R76-15K	3
R1013	47kΩ, 10%, 1/4W, Comp	44655	RC07-473-10%	R76-47K	1
R1014	15kΩ, 10%, 1/4W, Comp	44655	RC07-153-10%	R76-15K	..
R1015	8.45kΩ, 1%, 1/8W, MtF	07716	CEA-8.45kΩ	R88-8.45K	1
R1016	100kΩ, 10%, 1/4W, Comp.	44655	RC07-104-10%	R76-100K	..
R1017	27kΩ, 10%, 1/4W, Comp	44655	RC07-273-10%	R76-27K	..
R1018	15kΩ, 10%, 1/4W, Comp	44655	RC07-153-10%	R76-15K	..
R1019	10kΩ, 10%, 1/4W, Comp	44655	RC07-103-10%	R76-10K	2
R1020	10kΩ, 10%, 1/4W, Comp	44655	RC07-103-10%	R76-10K	..

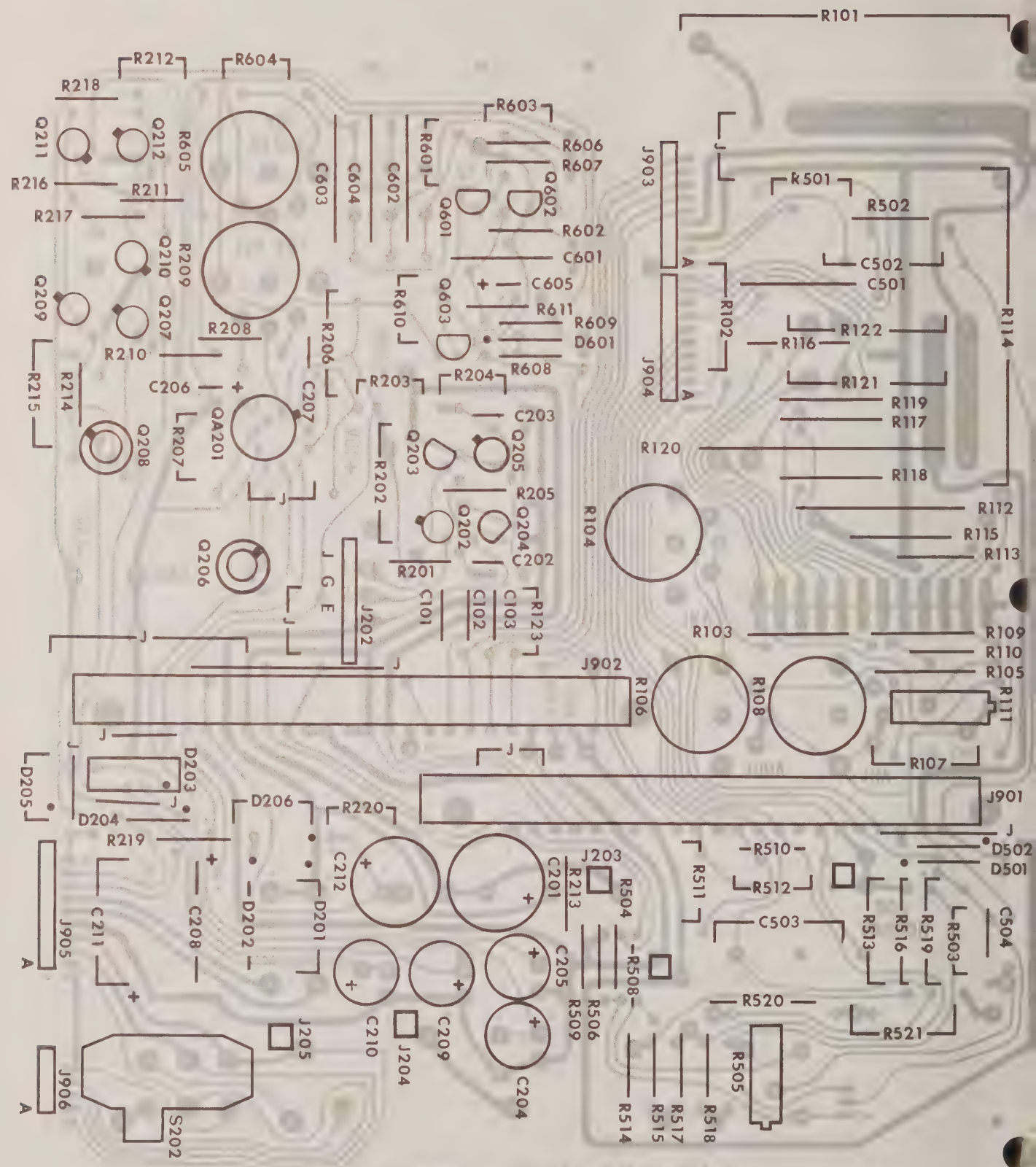


FIGURE 23. Component Layout, PC-254

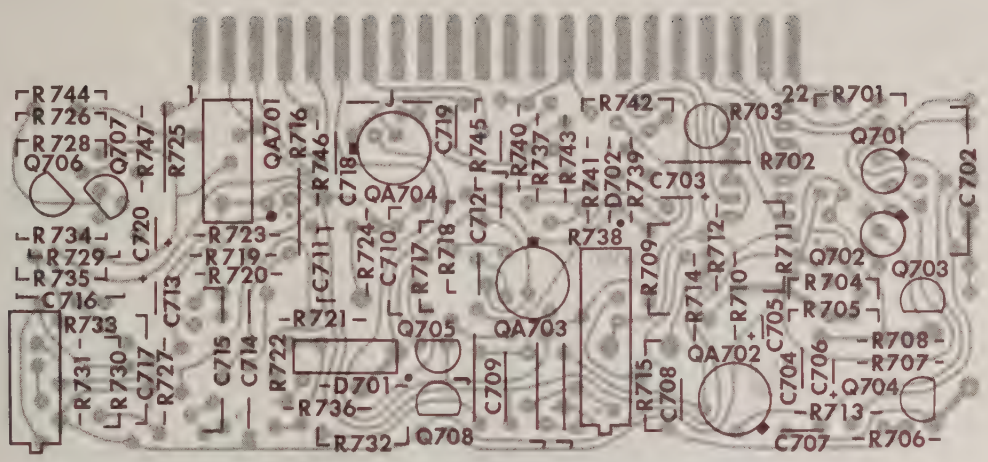


FIGURE 24. Component Layout, PC-251

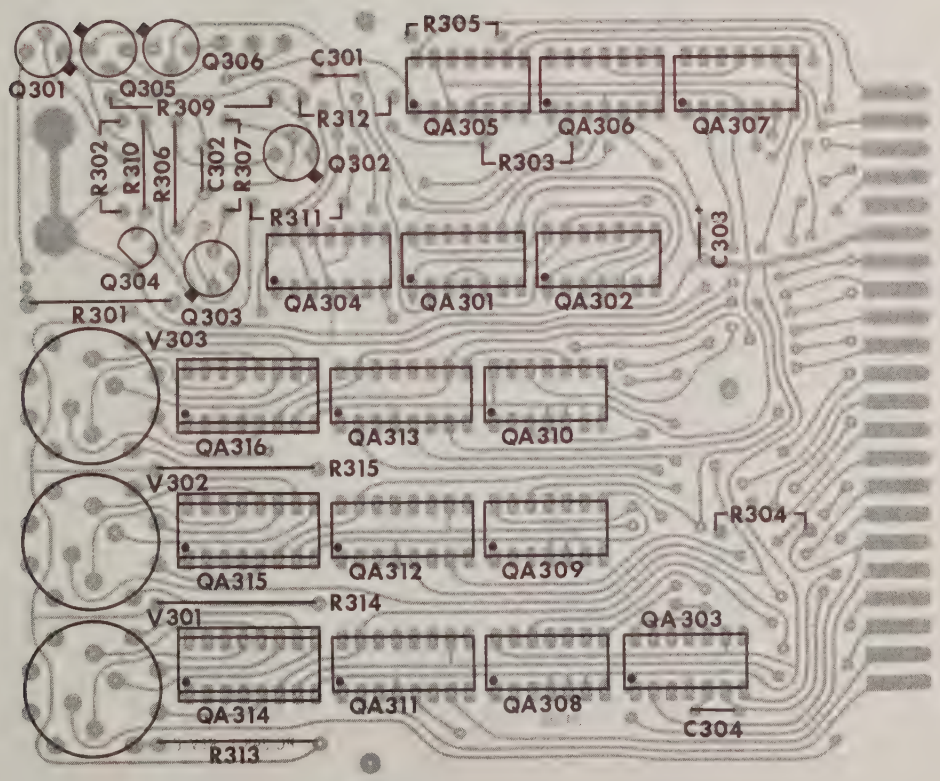


FIGURE 25. Component Layout, PC-248

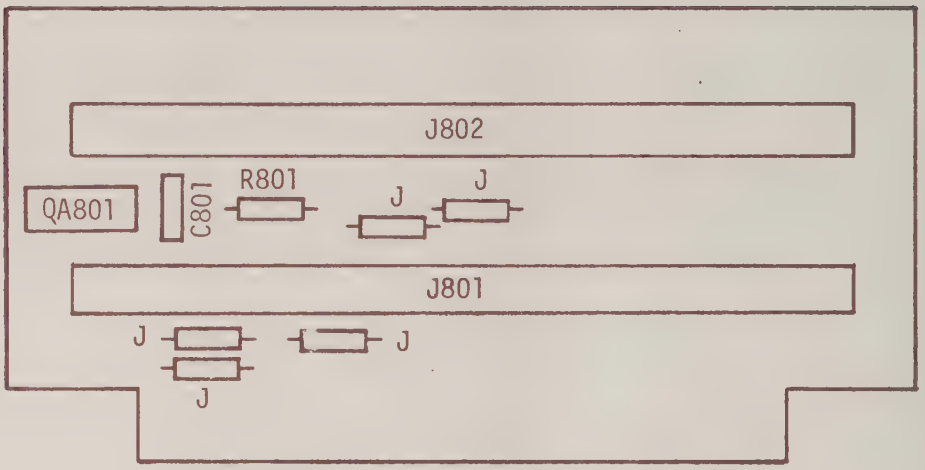


FIGURE 26. Component Layout, PC-255.

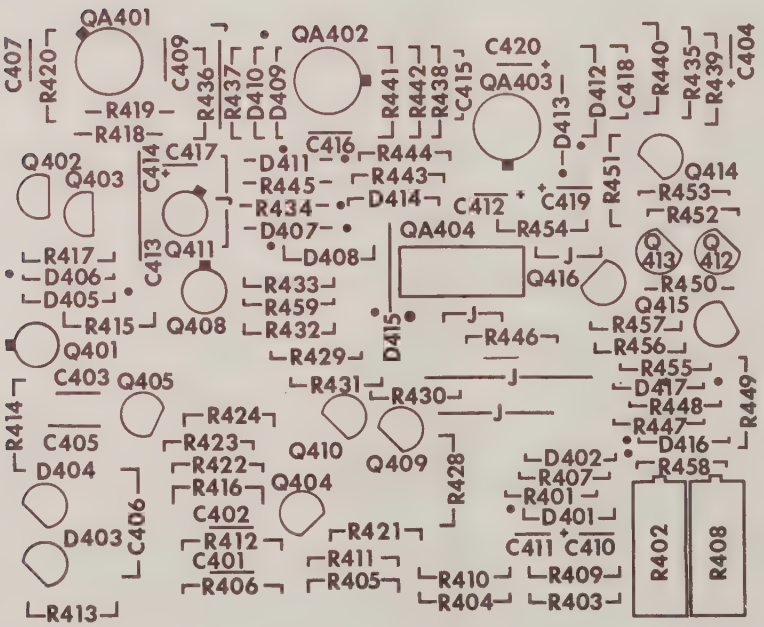


FIGURE 27. Component Layout, PC-250

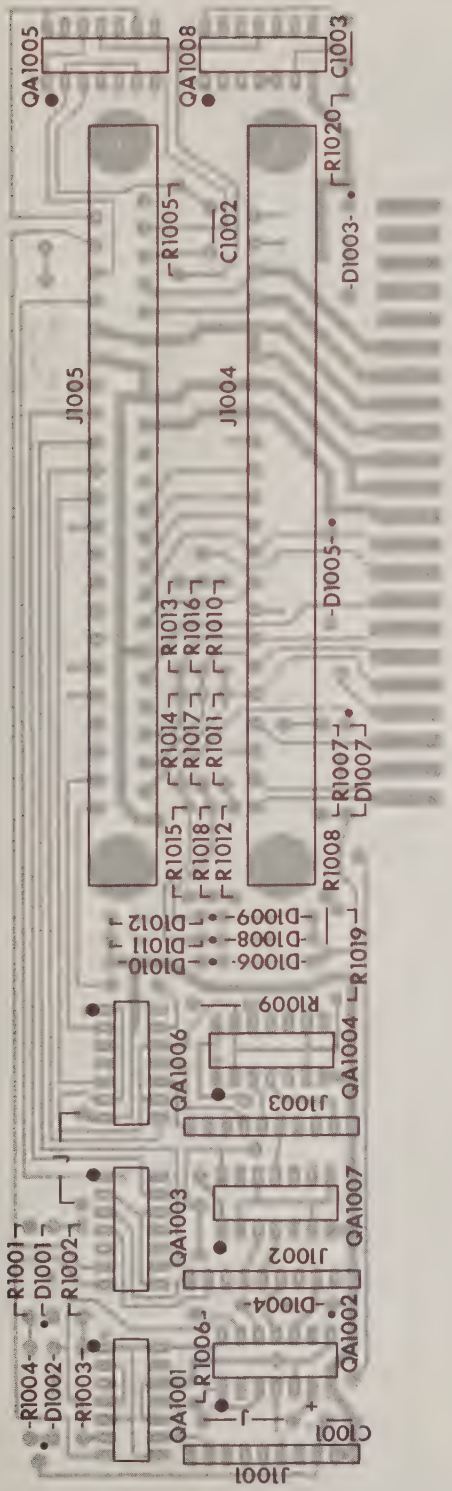


FIGURE 28. Component Layout, PC-287

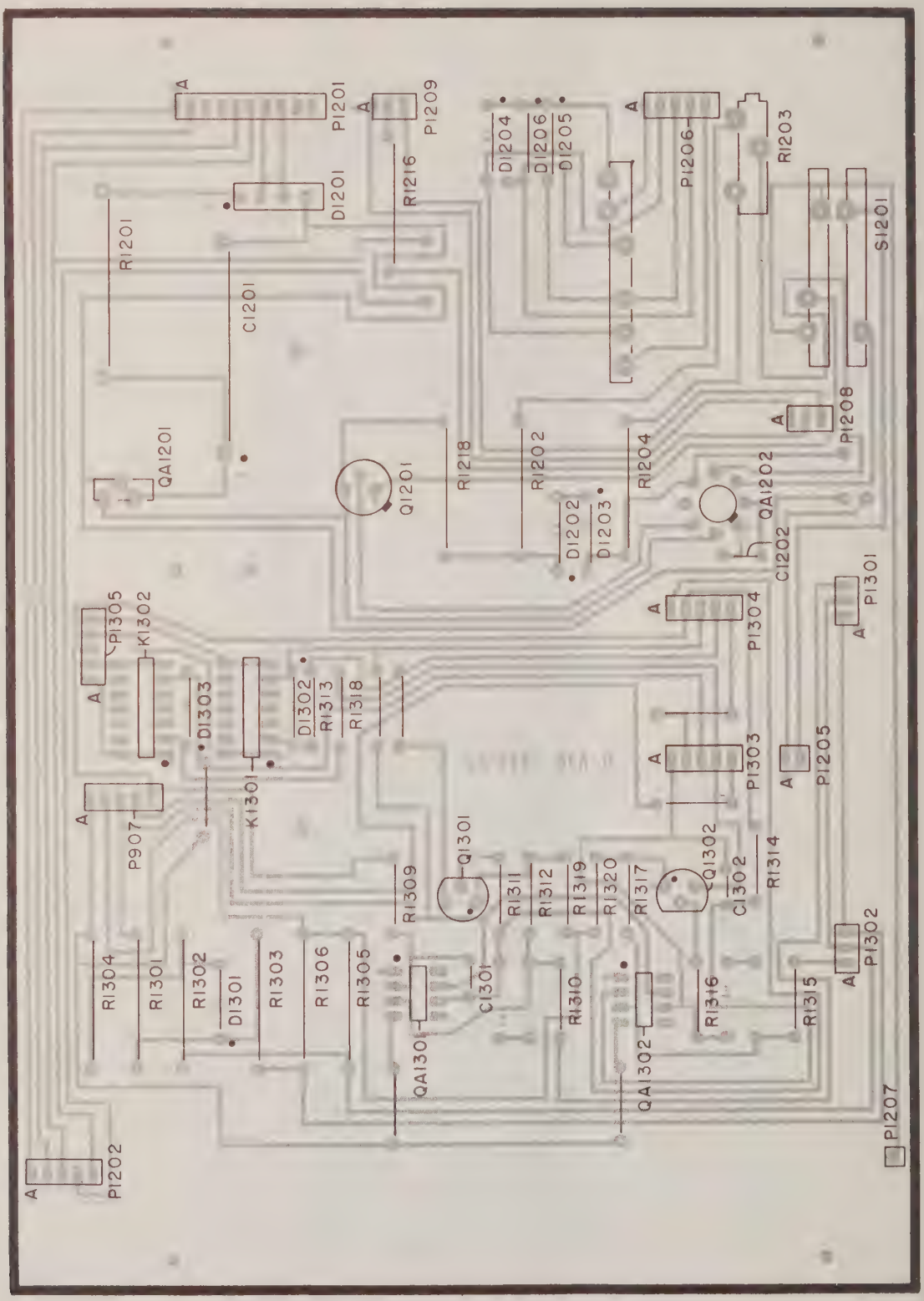
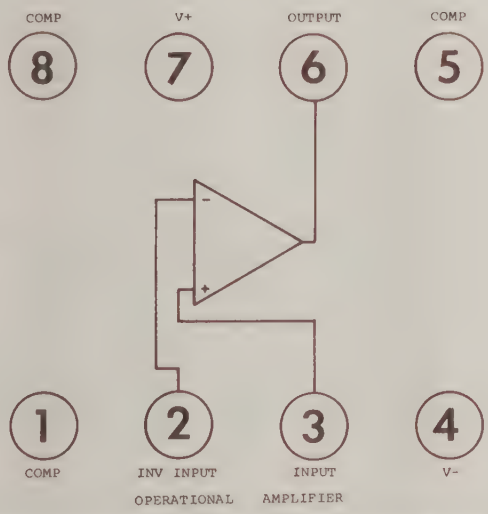


FIGURE 29. Component Layout, PC-348

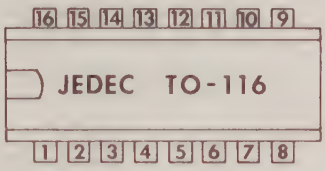
KEITHLEY PART NO. IC-1,2

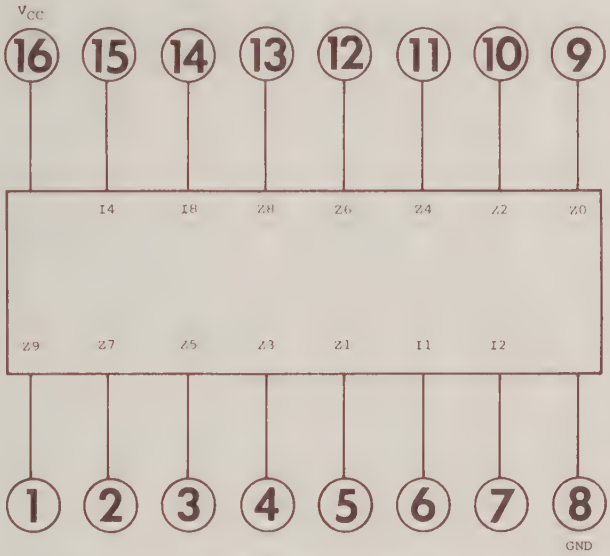
TO-99



OPERATIONAL AMPLIFIER

KEITHLEY PART NO. IC-3

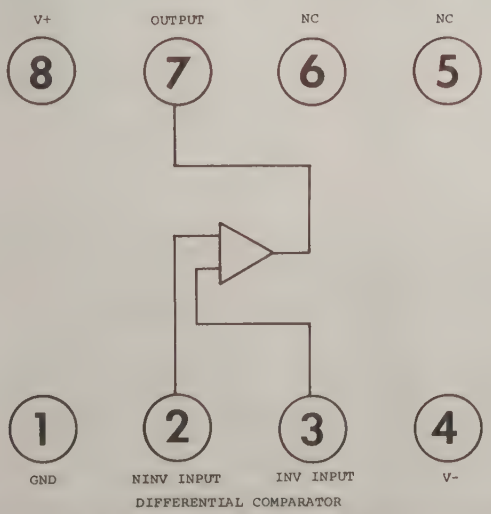




DECIMAL DECODER/DRIVER

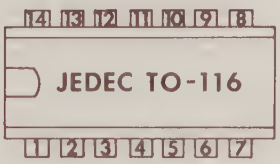
KEITHLEY PART NO. IC-4

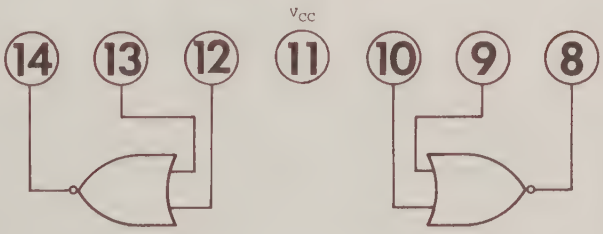
TO-99



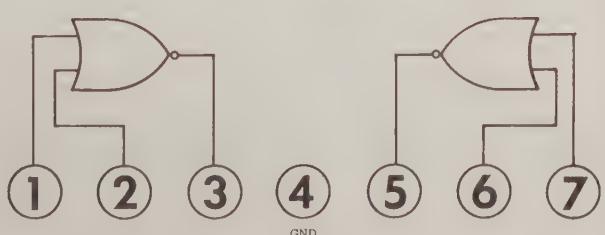
DIFFERENTIAL COMPARATOR

KEITHLEY PART NO. IC-5

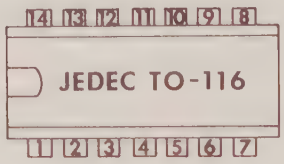


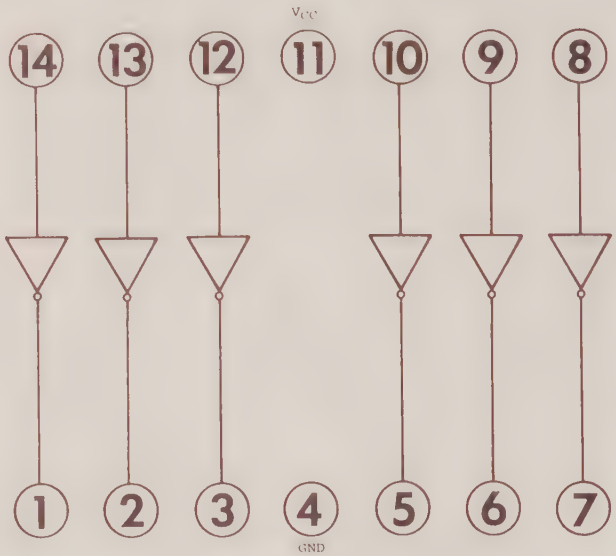


QUAD 2-INPUT GATES



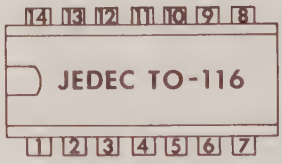
KEITHLEY PART NO. IC-7

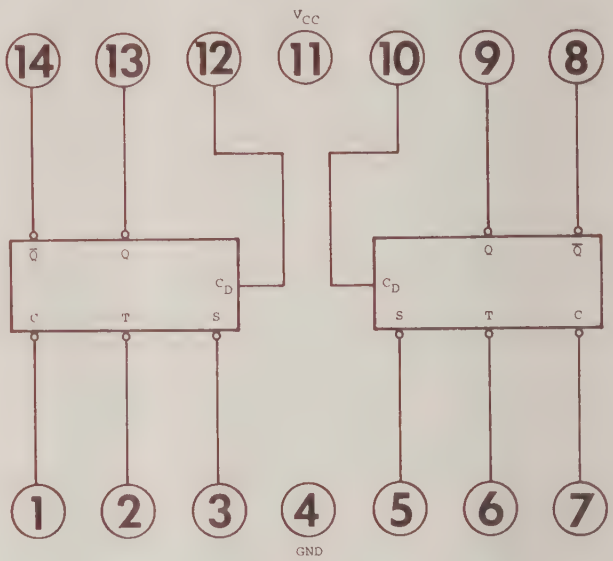




HEX INVERTER AMPLIFIER

KEITHLEY PART NO. IC-8,9

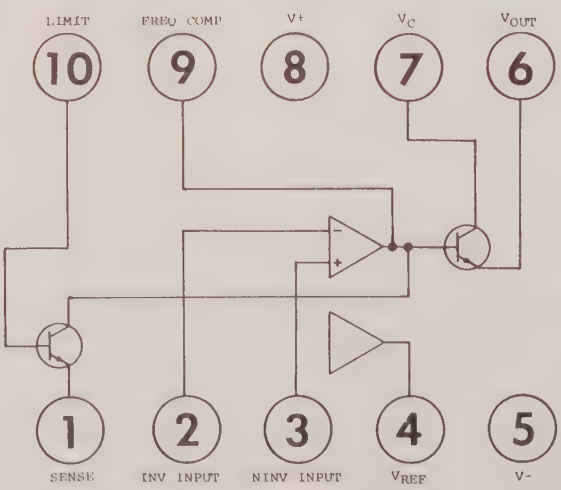




DUAL J-K FLIP FLOPS

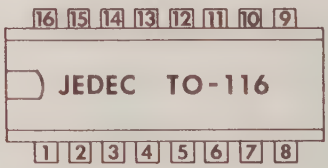
KEITHLEY PART NO. IC-14

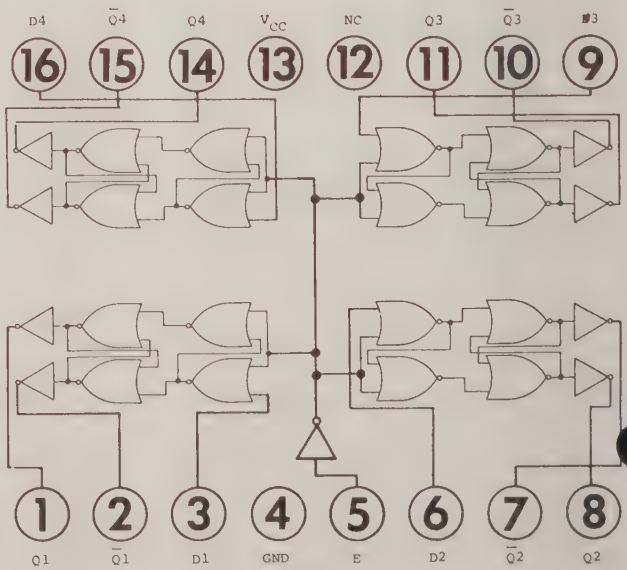
TO-100



REGULATOR

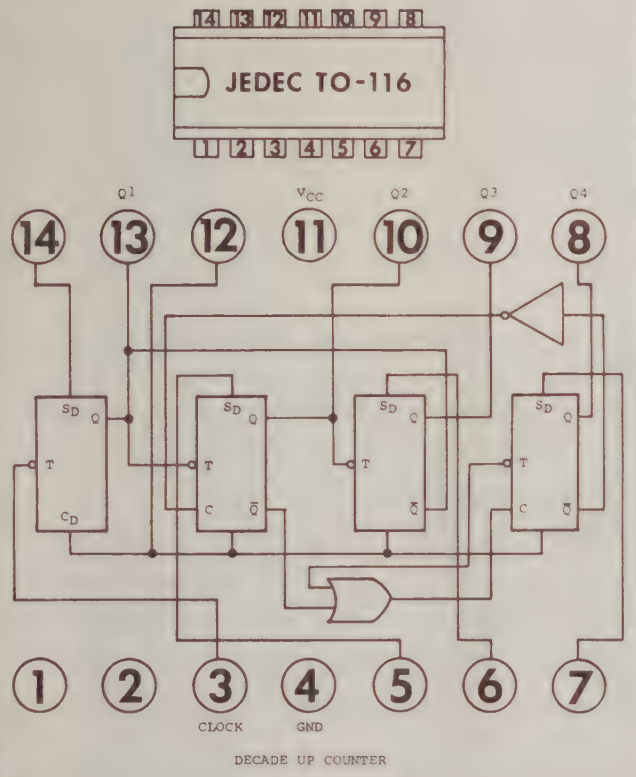
KEITHLEY PART NO. IC-16





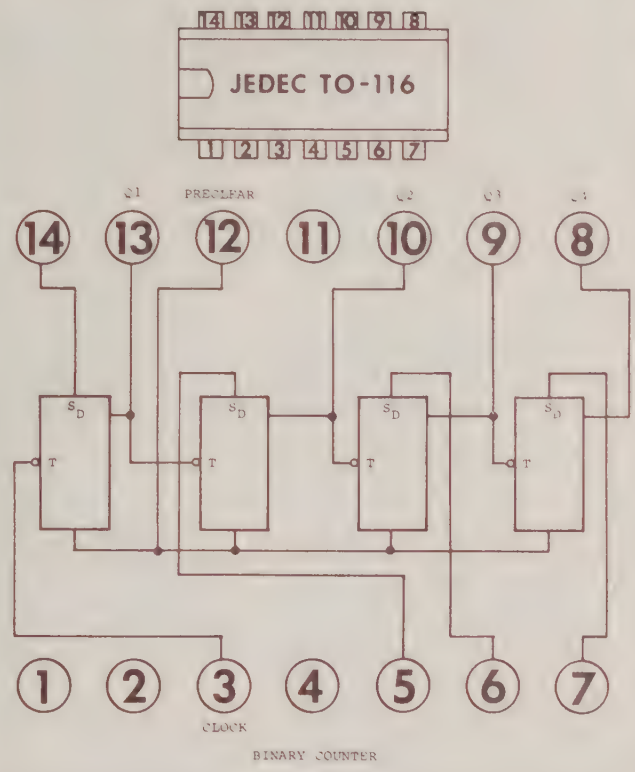
QUAD LATCH

KEITHLEY PART NO. IC-17



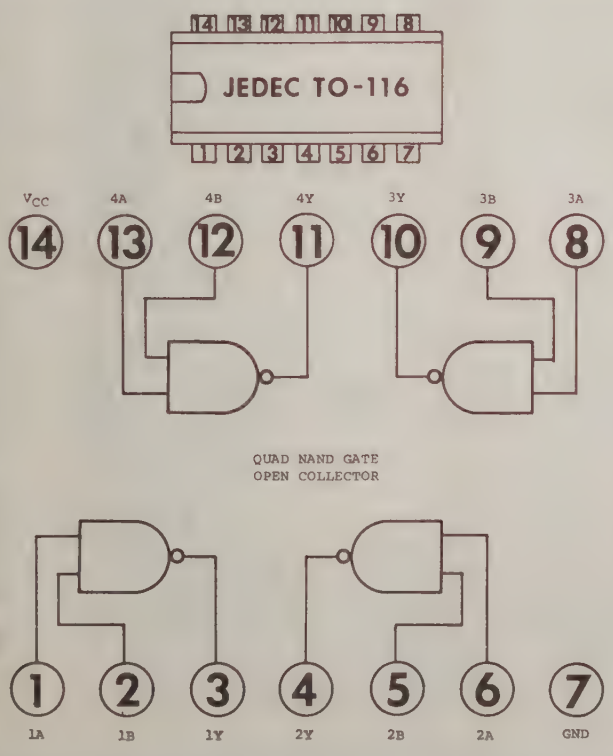
DECADE UP COUNTER

KEITHLEY PART NO. IC-21



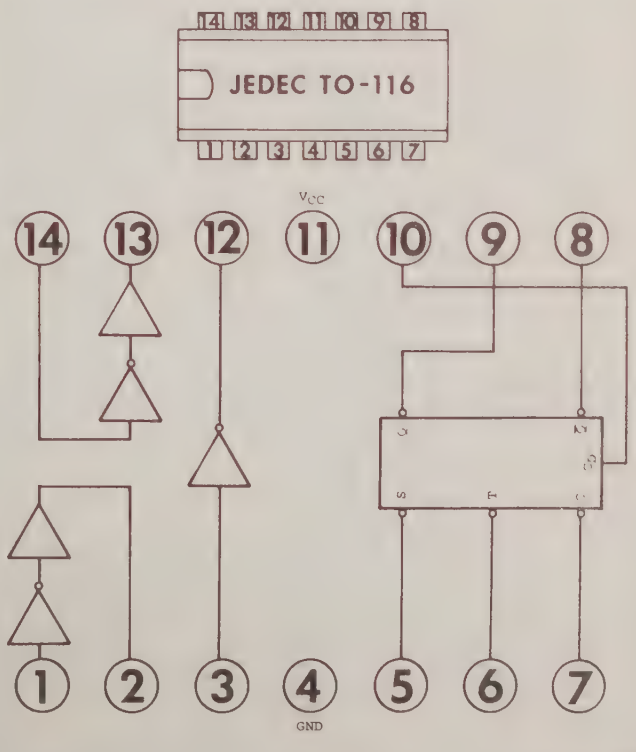
BINARY COUNTER

KEITHLEY PART NO. IC-22

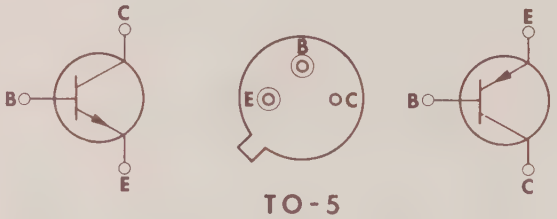


QUAD NAND GATE
OPEN COLLECTOR

KEITHLEY PART NO. IC-23



LEAD DESIG. TO-5



TO-5

LEAD DESIG. TO-92

TO-92

BOTTOM VIEW

LEAD DESIG. TO-104

TO-104

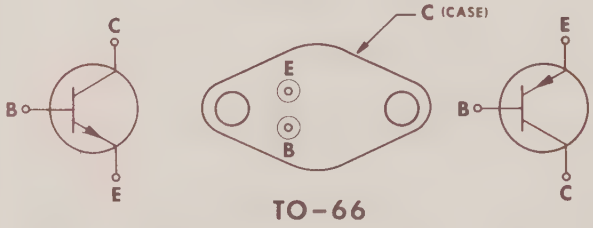
BOTTOM VIEW

LEAD DESIG. TO-106

TO-106

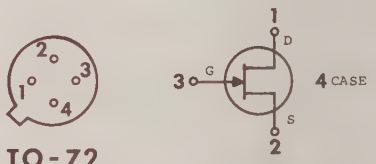
BOTTOM VIEW

LEAD DESIG. TO-66



TO-66

KEITHLEY PART NO. TG-42

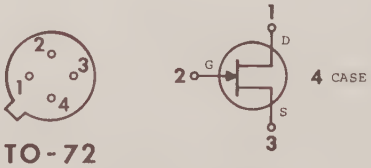


TO-72

BOTTOM VEIW

N-CHANNEL JFET

KEITHLEY PART NO. TG-51

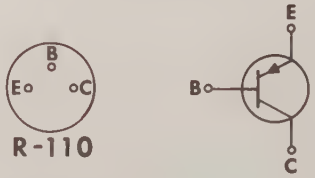


TO-72

BOTTOM VIEW

N-CHANNEL FET

KEITHLEY PART NO. TG-33



R-110

BOTTOM VIEW

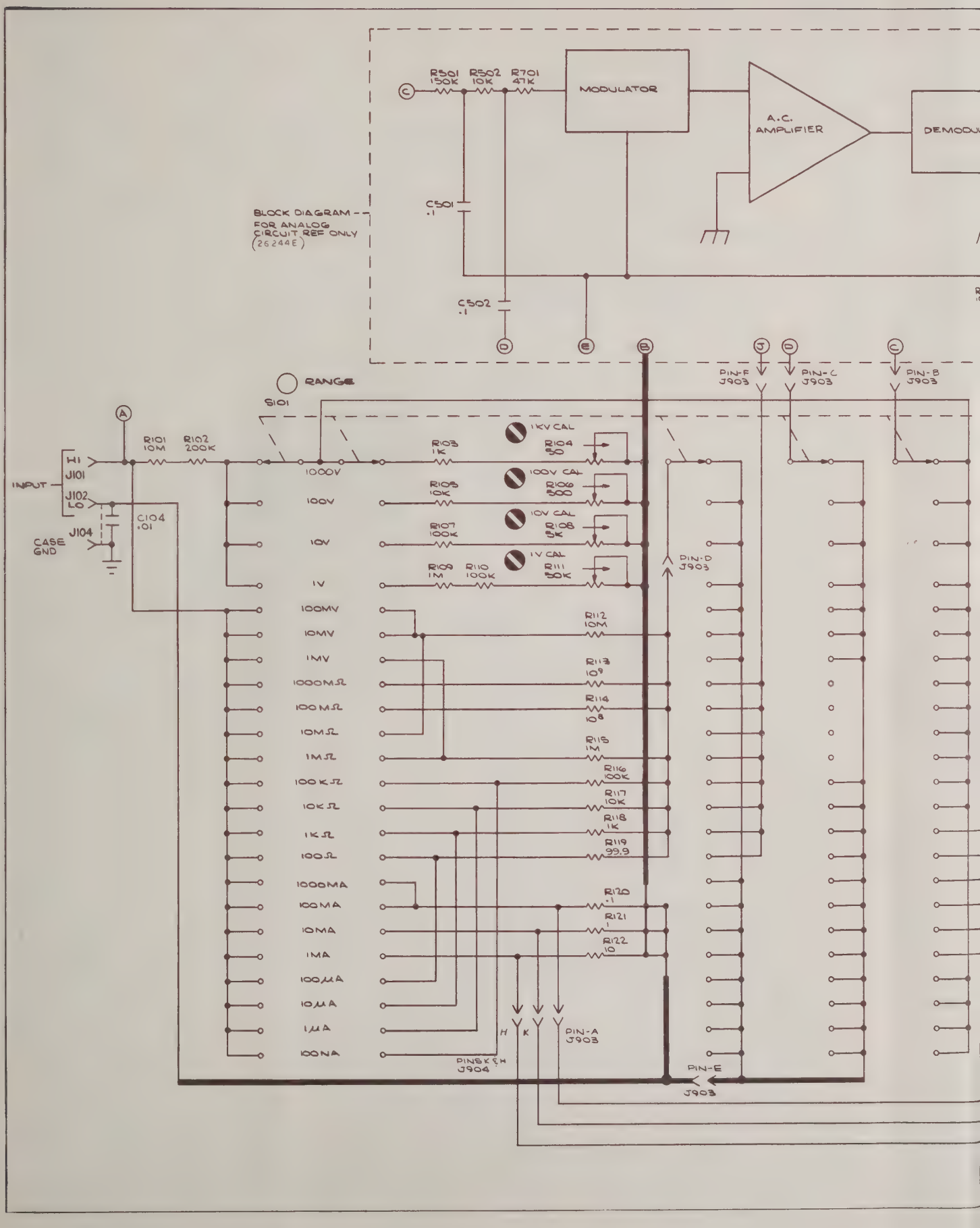
CODE—TO—NAME LIST

CODE TO NAME List of Suggested Manufacturers.
Reference: Federal Supply Code for Manufacturers, Cataloging Handbook H4-2.

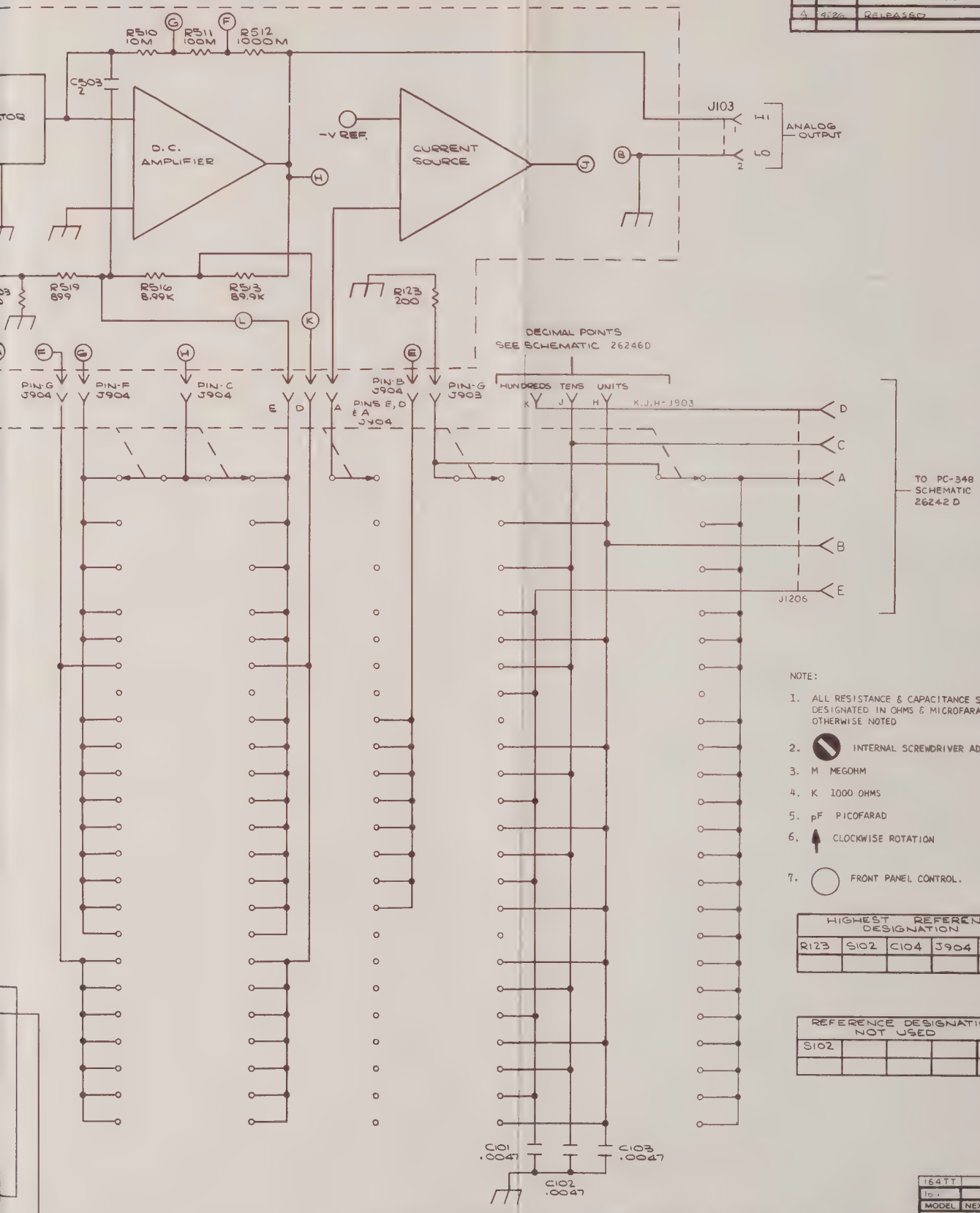
00656	Aerovox Corp. 740 Belleville Ave. New Bedford, Mass. 02741
00686	Film Capacitors, Inc. 100 Eighth St. Passaic, N.J.
01121	Allen-Bradley Corp. 1201 South 2nd St. Milwaukee, Wisc. 53204
01295	Texas Instruments, Inc. Semiconductor-Components Div. Dallas, Texas 75231
01686	RCL Electronics, Inc. 195 McGregor St. Manchester, N.H. 03102
02101	Varo Inc. Electrokinetics Div. Santa Barbara, Calif. 93102
02660	Amphenol Corp. 2801 South 25th Ave. Broadview, Ill. 60153
02734	Radio Corp. of America Defense Electronic Products Camden, N.J.
02735	Radio Corp. of America Receiving Tube Div. Somerville, N.J.
02777	Hopkins Engineering Co. 12900 Foothill Blvd. San Fernando, Calif. 91342
02985	Tepro Electric Corp. 5 St. Paul St. Rochester, N.Y. 14604
03508	General Electric Co. Semiconductor Products Dept. Syracuse, N.Y. 13201
04009	Arrow-Hart & Hegeman Electric Co. 103 Hawthorne St. Hartford, Conn. 06106
04713	Motorola Semiconductor Prod. Inc. 5005 E. McDowell Rd. Phoenix, Ariz. 85008
05079	Tansistor Electronics, Inc. 1000 West Road Bennington, Vt. 05201
05397	Union Carbide Corp. Electronics Div. New York, N.Y. 10017
06751	Components, Inc. Arizona Div. Phoenix, Ariz. 85019
06980	Varian Assoc. EIMAC Div. 301 Industrial Way San Carlos, Calif. 94070
07137	Transistor Electronics Corp. Hwy. 169 - Co. Rd. 18 Minneapolis, Minn. 55424
07263	Fairchild Camera & Inst. Corp. 313 Frontage Road Mountain View, Calif.
07716	IRC, Inc. 2850 Mt. Pleasant Burlington, Iowa 52601
08811	GL Electronics Div. of GL Industries, Inc. Westville, N.J. 08093
09052	Gulton Industries, Inc. Alkaline Battery Div. Metuchen, N.J.
09823	Burgess Battery Co. Div. of Servel Inc. Freeport, Ill.
09922	Burndy Corp. Richards Ave. Norwalk, Conn. 06852
10582	CTS of Asheville Inc. Mills Gap Road Skyland, N.C.
11502	IRC Inc. Greenway Road Boone, N.C. 28607
11837	Electro Scientific Indus., Inc. 13645 NW Science Park Dr. Portland, Or. 97229
12040	National Semiconductor Corp. Commerce Drive Danbury, Conn. 06813
12065	Transitron Electronic Corp. 144 Addison St. East Boston, Mass.
12697	Clarostat Mfg. Co., Inc. Lower Washington St. Dover, N.H. 03820
12954	Dickson Electronics Corp. 302 S. Wells Fargo Ave. Scottsdale, Ariz.
13050	Potter Co. Highway 51 N. Wesson, Miss. 39191
13327	Solitron Devices, Inc. 256 Oak Tree Road Tappan, N.Y. 10983
13934	Midwec Corp. 602 Main Oshkosh, Nebr. 69154
14655	Cornell-Dubilier Electric Corp. 50 Paris Street Newark, N.J.
14659	Sprague Electric Co. P.O. Box 1509 Visalia, Calif. 93278
15238	ITT Semiconductors Div. of ITT Corp. Lawrence, Mass. 01841
15909	Daven Div. of T.A. Edison Ind. McGraw Edison Co. Livingston, N.J.
16170	Teledyne Systems Co. Communications Div. Los Angeles, Calif. 90066
17554	Components, Inc. Smith St. Biddeford, Ma. 04005
23020	General Reed Co. 174 Main St. Metuchen, N.J. 08840
24655	General Radio Co. 22 Baker Ave. West Concord, Mass. 01781
27682	Hathaway Instruments, Inc. 5800 E. Jewell Ave. Denver, Colorado 80222
28520	Heyman Mfg. Co. 147 N. Michigan Ave. Kenilworth, N.J.
29309	Richey Electronics Inc. 1307 Dickerson Rd. Nashville, Tenn. 37213
35529	Leeds and Northrup 4901 Stenton Ave. Philadelphia, Pa. 19144
37942	Mallory, P. R. and Co., Inc. 3029 E. Washington St. Indianapolis, Ind. 46206
44655	Ohmite Mfg. Co. 3601 Howard St. Skokie, Ill. 60076
53201	Sangamo Electric Co. 1301 North 11th Springfield, Ill. 62705
54294	Shallcross Mfg. Co. 24 Preston St. Selma, N.C.
56289	Sprague Electric Co. North Adams, Massachusetts
58474	Superior Electric Co., The 383 Middle St. Bristol, Conn. 06012
61637	Union Carbide Corp. 270 Park Ave. New York, N.Y. 10017

CODE TO NAME List (Continued).

63060	Victoreen Instrument Co. 5806 Hough Ave. Cleveland, Ohio 44103
70309	Allied Control Co., Inc. 2 East End Ave. New York, N.Y.
70903	Belden Mfg. Co. 415 So. Kilpatrick Chicago, Ill. 60644
71002	Birnbach Radio Co., Inc. 147 Hudson St. New York, N.Y.
71279	Cambridge Thermionic Corp. 430 Concord Avenue Cambridge, Mass.
71400	Bussmann Mfg. Div. of McGraw-Edison Co. St. Louis, Mo.
71450	CTS Corp. 1142 W. Beardsley Ave. Elkhart, Ind.
71468	ITT Cannon Electric, Inc. 3208 Humbolt St. Los Angeles, Calif. 90031
71590	Centralab Div. of Globe-Union, Inc. Milwaukee, Wisc. 53212
71785	Cinch Mfg. Co. and Howard B. Jones Div. Chicago, Ill. 60624
72619	Dialight Corp. 60 Stewart Ave. Brooklyn, N.Y. 11237
72653	G-C Electronics Co. 400 S. Wyman Rockford, Ill. 61101
72699	General Instrument Corp. Capacitor Division Newark, N.J. 07104
72982	Erie Technological Prods Inc. 644 W. 12th St. Erie, Pa. 16512
73138	Beckman Instruments, Inc. Helipot Division Fullerton, Calif. 92634
73445	Amperex Electronic Co., Div. of North American Philips Co., Inc. Hicksville, N.Y.
73690	Elco Resistor Co. 1158 Broadway New York, N.Y.
74276	Signalite Inc. 1933 Heck Ave. Neptune, N.J. 07753
74970	Johnson, E. F., Co. 297 Tenth Ave. S.W. Waseca, Minn. 56093
75042	IRC Inc. 401 North Broad St. Philadelphia, Pa. 19108
75915	Littlefuse, Inc. 800 E. Northwest Hwy. Des Plaines, Ill. 60016
76055	Mallory Controls, Div. of Mallory P. R. & Co., Inc. Frankfort, Ind.
76493	Miller, J. W. Co. 5915 S. Main St. Los Angeles, Calif. 90003
76545	Mueller Electric Co. 1583 E. 31st St. Cleveland, Ohio 44114
77764	Resistance Products Co. 914 S. 13th St. Harrisburgh, Pa. 17104
79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.
80164	Keithley Instruments, Inc. 28775 Aurora Road Cleveland, Ohio 44139
80294	Bourns, Inc. 6135 Magnolia Ave. Riverside, Calif. 92506
81073	Grayhill, Inc. 561 Hillgrove Ave. La Grange, Ill. 60525
81483	International Rectifier Corp. 1523 East Grand Ave. El Segundo, Calif.
82389	Switchcraft, Inc. 5527 N. Elston Ave. Chicago, Ill. 60630
83125	General Instrument Corp. Capacitor Division Darlington, S.C. 29532
83330	Smith, Herman H., Inc. 812 Snediker Ave. Brooklyn, N.Y. 11207
83594	Burroughs Corp. Electronic Components Div. Plainfield, N.J. 07061
83701	Electronic Devices, Inc. Brooklyn, New York
84171	Arco Electronics, Inc. Community Drive Great Neck, N.Y. 11022
84411	TRW Capacitor Div. 112 W. First St. Ogallala, Nebr.
84970	Sarkes Tarzian, Inc. E. Hillside Dr. Bloomington, Ind.
86684	Radio Corp. of America Electronic Components & Devices Harrison, N.J.
87216	Philco Corp. Lansdale Div., Church Rd. Lansdale, Pa. 19446
90201	Mallory Capacitor 3029 East Washington Indianapolis, Ind. 46206
90303	Mallory Battery Co. Tarrytown, New York
91637	Dale Electronics, Inc. P.O. Box 609 Columbus, Nebr. 68601
91662	Elco Corp. Willow Grove, Pennsylvania
91737	Gremar Mfg. Co., Inc. 7 North Ave. Wakefield, Mass.
91802	Industrial Devices Inc. 982 River Rd. Edgewater, N.J. 07020
91929	Honeywell Inc. Micro Switch Div. Freeport, Ill. 61032
93332	Sylvania Electric Products, Inc. Semiconductor Products Div. Woburn, Mass.
93656	Electric Cord Co. 1275 Bloomfield Ave. Caldwell, N.J.
94144	Raytheon Co., Industrial Operation Components Div. Quincy, Mass.
94154	Tung-Sol Electric, Inc. Newark, New Jersey
94310	Tru-Ohm Products Memcor Components Div. Huntington, Ind. 46750
94696	Magnecraft Electric Co. 5579 North Lynch Chicago, Ill.
95348	Gordos Corp. 250 Glenwood Ave. Bloomfield, N.J. 07003
95712	Dage Electric Co., Inc. Hurricane Road Franklin, Ind.
97933	Raytheon Co. Components Div. Semiconductor Operation Mountain View, Calif.
99120	Plastic Capacitors, Inc. 2620 N. Clybourn Ave. Chicago, Ill.


BLOCK DIAGRAM
FOR ANALOG
CIRCUIT REF ONLY
(26244E)
R501 150K
R502 10K
R701 47K
MODULATOR
A.C. AMPLIFIER
C501 .1
C502 .1
RANGE
S101
INPUT
H1 J101
J102 LO
J104 CASE GND
C104 .01
R101 10M
R102 200K
R103 1K
R104 50
1KV CAL
R105 10K
R106 500
100V CAL
R107 100K
R108 5K
10V CAL
R109 1M
R110 100K
R111 50K
1V CAL
1000V
100V
10V
1V
100MV
10MV
1MV
1000MΩ
100MΩ
10MΩ
1MΩ
100KΩ
10KΩ
1KΩ
100Ω
1000MA
100MA
10MA
1MA
100μA
10μA
1μA
100NA
R112 10M
R113 10^9
R114 10^8
R115 1M
R116 100K
R117 10K
R118 1K
R119 99.9
R120 .1
R121 1
R122 10
PIN-F J903
PIN-C J903
PIN-B J903
PIN-D J903
PIN-A J903
PIN-E J903
PINS K,H J904
H
K

LTR	ECO NO.	REVISION	DATE
A	9226	RELEASED	1-16-79



NOTE:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED
2. INTERNAL SCREWDRIVER ADJ.
3. M MEGOHM
4. K 1000 OHMS
5. pF PICOFARAD
6. CLOCKWISE ROTATION
7. FRONT PANEL CONTROL.

HIGHEST REFERENCE DESIGNATION				
R123	S102	C104	J904	J1206

REFERENCE DESIGNATIONS NOT USED				
S102				

164TT			
10			
MODEL	NEXT ASSEMBLY	QTY.	
USED ON			

DO NOT SCALE THIS DRAWING

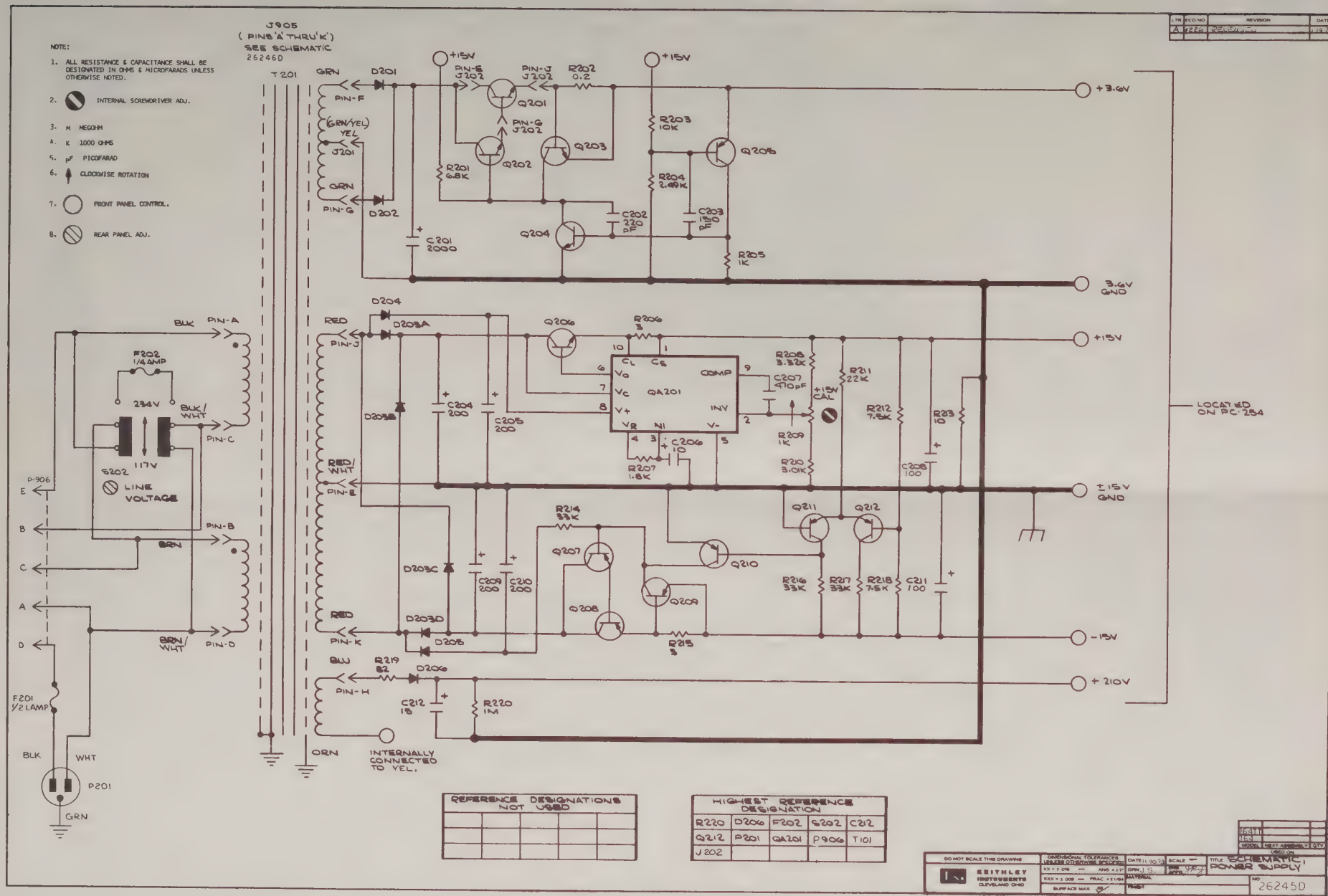
KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX = ± .015 — ANG. = ±1°
XXX = ± .005 — FRAC. = ±1/64
SURFACE MAX. 63

DATE
DRNG ECHA
ENG APPR. JRF
MATERIAL
FINISH
SCALE —

TITLE SCHEMATIC, SWITCHING

NO. 26243E



REFERENCE DESIGNATIONS NOT USED				

HIGHEST REFERENCE DESIGNATION				
R220	D206	F202	6202	C212
Q212	P201	QA201	P906	T101
J202				

LTR	ECO NO	REVISION	DATE
A	6226	RELEASED	11-9-72

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

DATE 11-9-72 SCALE —

DRN. JS

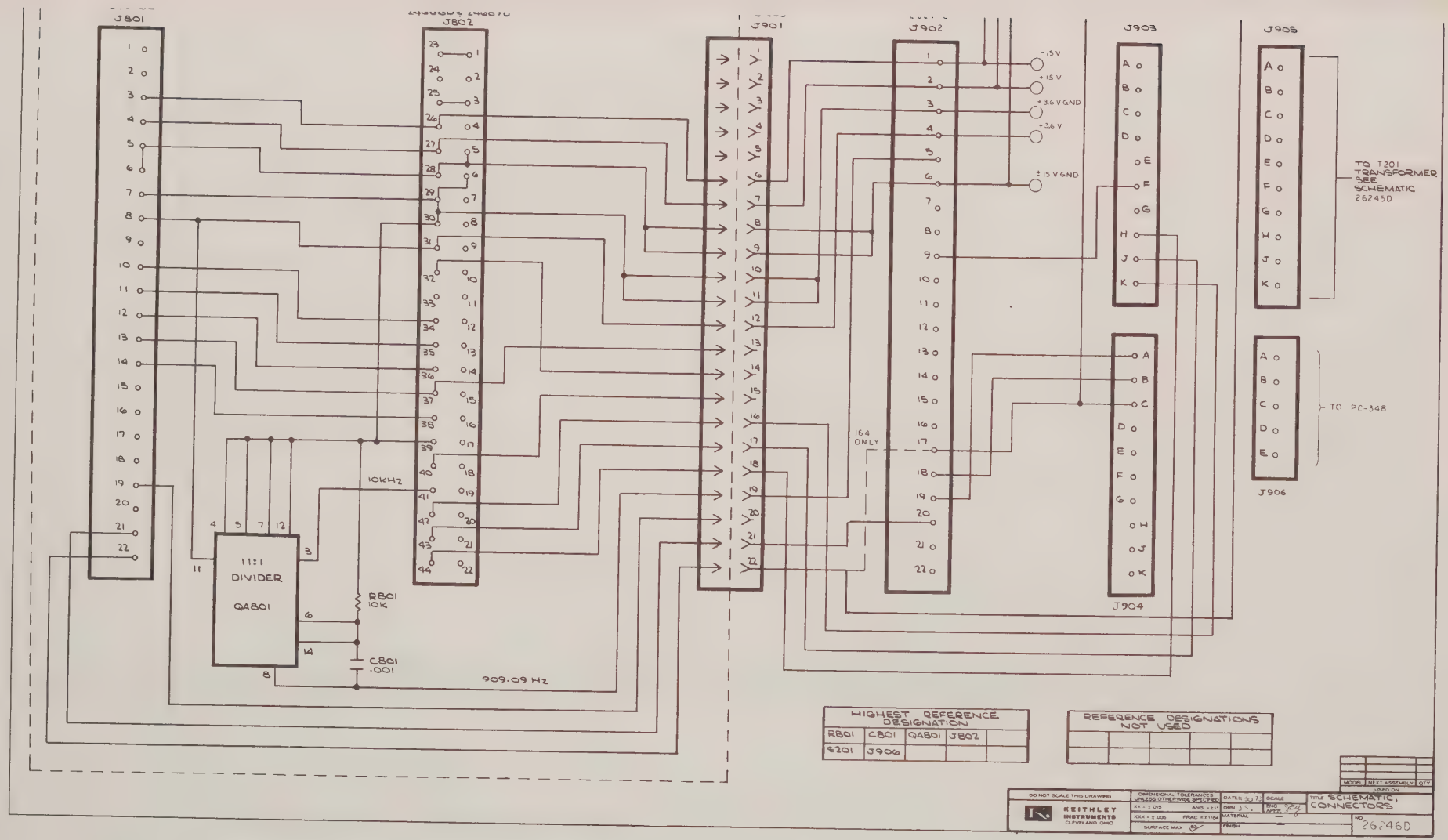
MATERIAL

FINISH

TITLE SCHEMATIC, POWER SUPPLY

USED ON

NO 26245D



HIGHEST REFERENCE DESIGNATION				
R801	C801	Q4801	J802	
E201	J906			

REFERENCE DESIGNATIONS NOT USED

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND OHIO

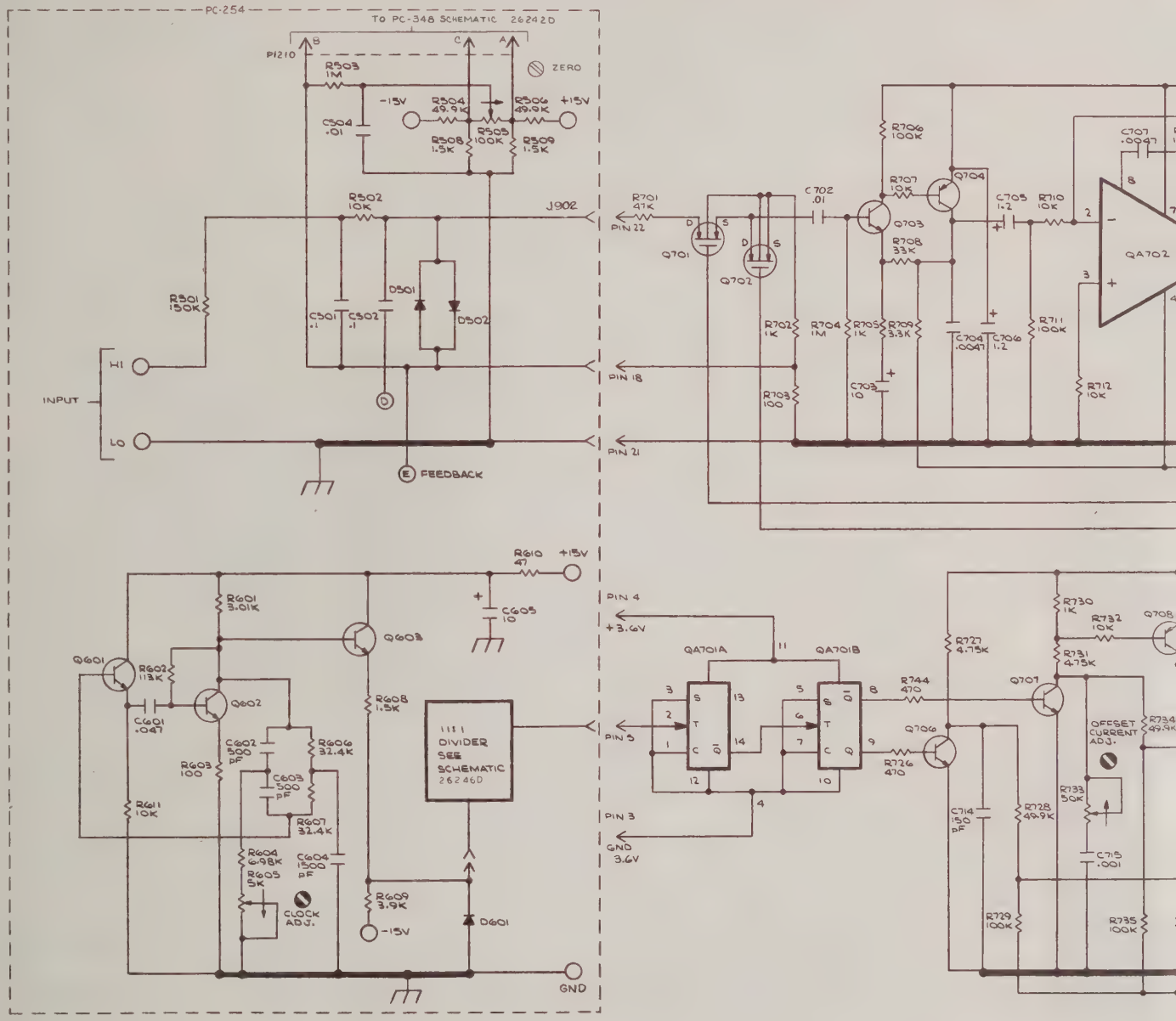
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX ± .010 ANG ± 2°
XXX ± .005 FRAC ± 1/64
SURFACE MAX 63

DATE 11-30-71 SCALE
DRN J.S. TRD
MATERIAL —
FINISH

TITLE SCHEMATIC, CONNECTORS

NO 26246D

MODEL NEXT ASSEMBLY QTY
USED ON

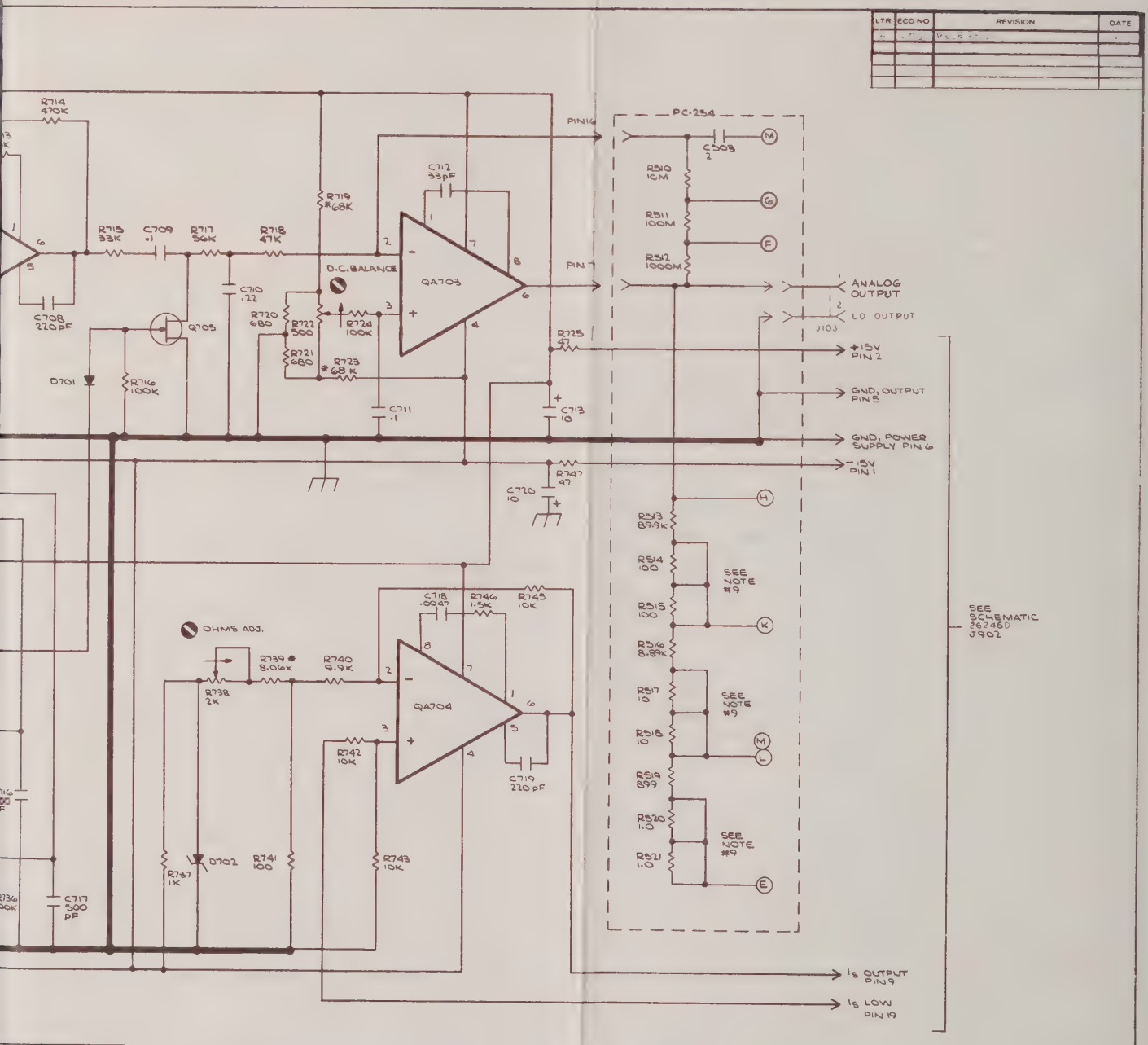


NOTE:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. INTERNAL SCREWDRIVER ADJ.
3. REAR PANEL ADJ.
4. M MEGOHM
5. K 1000 OHMS
6. pF PICOFARAD
7. CLOCKWISE ROTATION
8. * INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION.
9. JUMPERS CLIPPED DURING FINAL CALIBRATION IS NECESSARY.

HIGHEST SCHEMATIC DESIGNATIONS					
R521	C504		J902	D502	
R611	C605	D601	Q603		
R747	C720	D702	Q708	QA704	D208

SCHEMATIC NOT		
C701	D5501	
R507		
J901		



LTR	ECO NO	REVISION	DATE

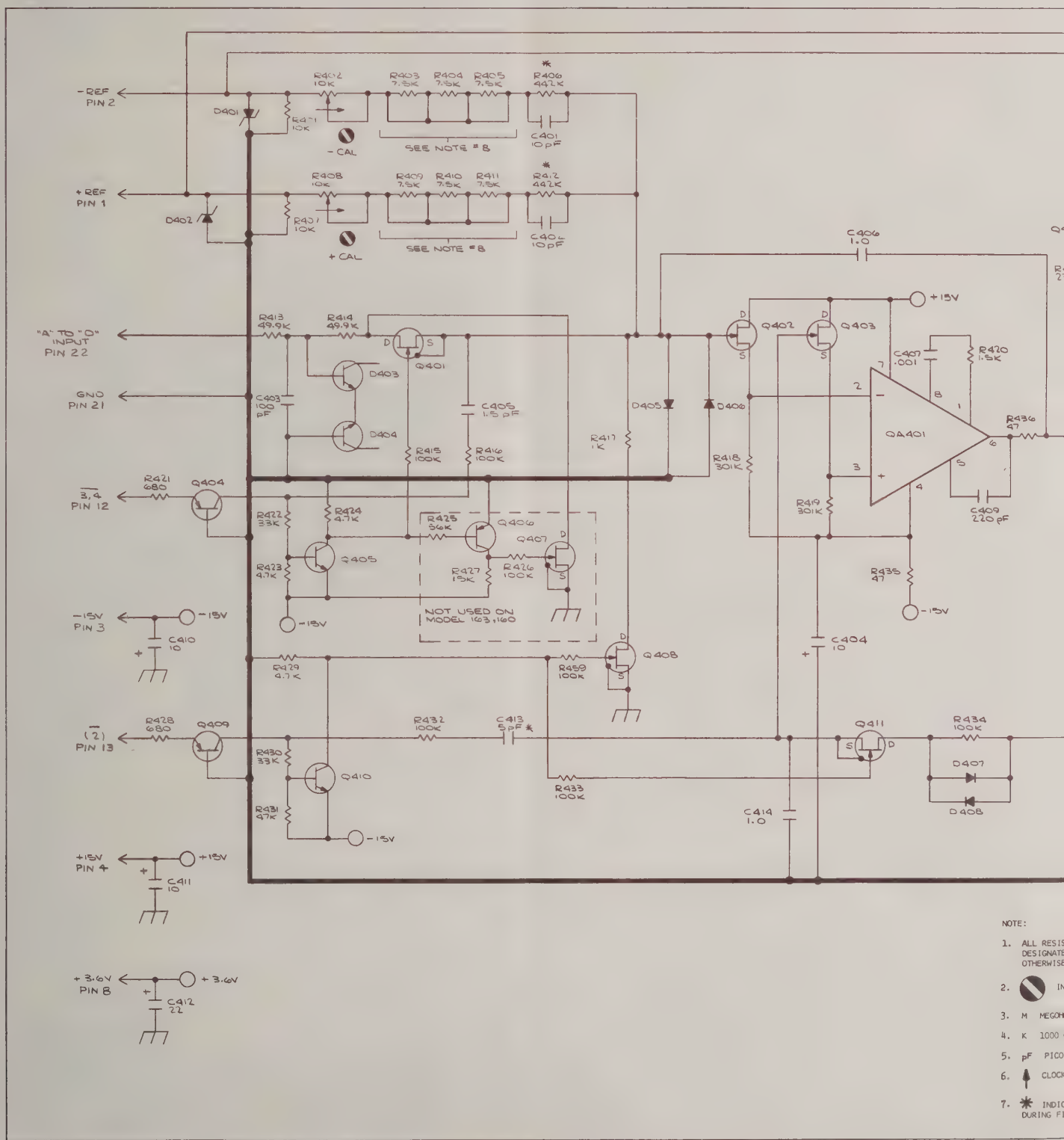
DESIGNATIONS ED		

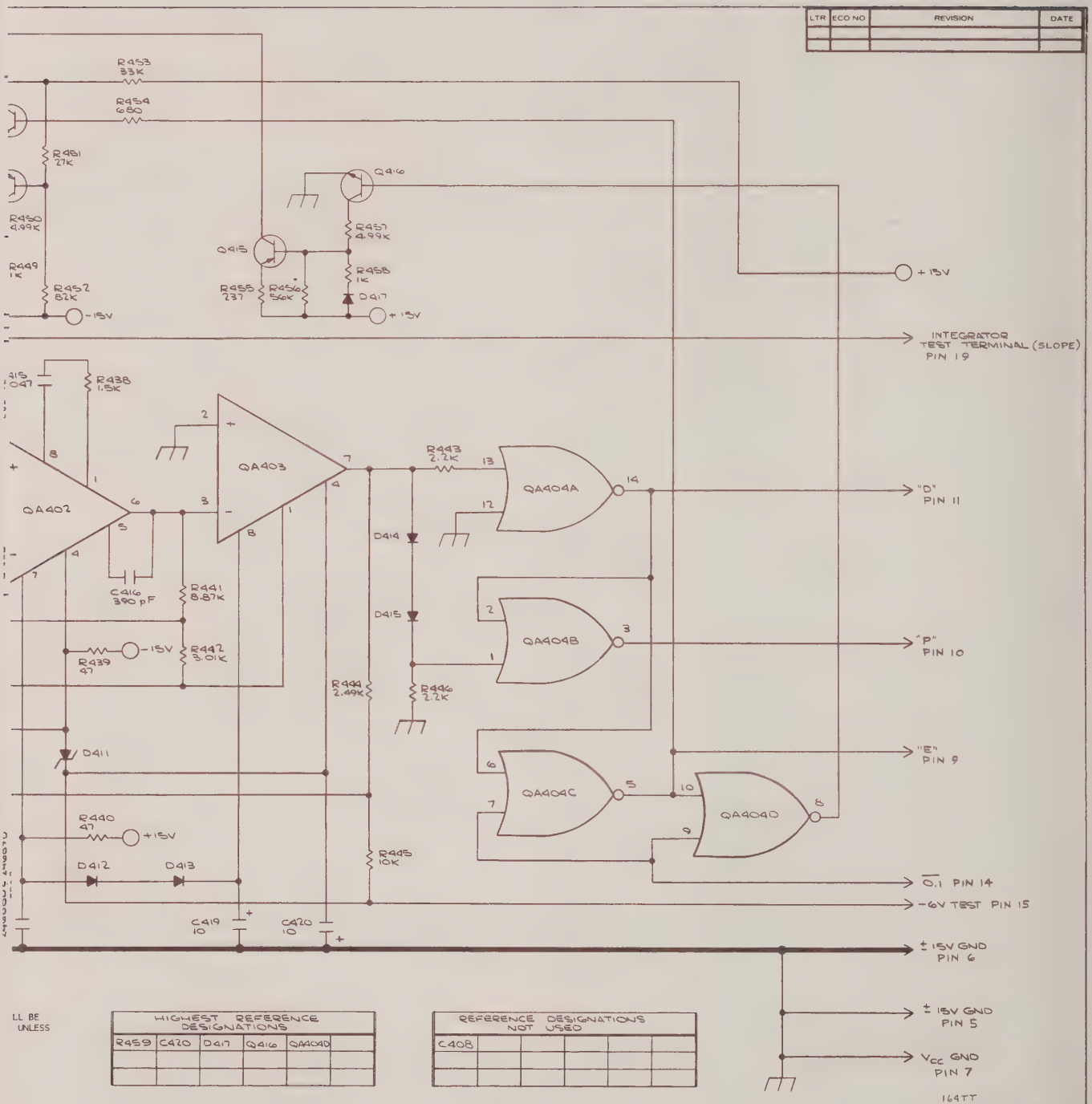
164 T T			
64			
MODEL	NEXT ASSEMBLY	QTY	
USED ON			

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE	SCALE
KEITHLEY INSTRUMENTS CLEVELAND, OHIO	XX = ± .015 — ANG = ±1°	DRN	ENG APPR
	XXX = ± .005 — FRAC = ±1/64	MATERIAL	
	SURFACE MAX 63	FINISH	

TITLE SCHEMATIC, ANALOG AMPLIFIER PC-251

NO 26244E


-REF PIN 2
+REF PIN 1
"A" TO "D" INPUT PIN 22
GND PIN 21
3,4 PIN 12
-15V PIN 3
(2) PIN 13
+15V PIN 4
+3.6V PIN 8
D401
D402
R401 10K
R402 10K
R403 7.5K
R404 7.5K
R405 7.5K
R406 442K
C401 10 pF
- CAL
SEE NOTE * 8
R407 10K
R408 10K
R409 7.5K
R410 7.5K
R411 7.5K
R412 442K
C402 10 pF
+ CAL
R413 49.9K
R414 49.9K
Q401
D403
D404
C403 100 pF
C405 1.5 pF
R415 100K
R416 100K
R417 1K
D405
D406
R418 301K
C406 1.0
+15V
Q402
Q403
C407 .001
R420 1.5K
QA401
R436 47
C409 220 pF
R419 301K
R435 47
-15V
R421 680
Q404
R422 33K
R424 4.7K
R425 56K
Q406
Q407
R423 4.7K
Q405
R427 15K
R426 100K
NOT USED ON MODEL 163,160
C404 10
R429 4.7K
R459 100K
Q408
R428 680
Q409
R432 100K
C413 5 pF *
R430 33K
Q410
R431 47K
R433 100K
Q411
R434 100K
D407
D408
C414 1.0
C410 10
C411 10
C412 22
NOTE:
1. ALL RESIS DESIGNATE OTHERWISE
2. IN
3. M MEGOH
4. K 1000
5. pF PICO
6. CLOCK
7. * INDIC DURING FI



LTR	ECO NO	REVISION	DATE

LL BE UNLESS

HIGHEST REFERENCE DESIGNATIONS					
R459	C420	D417	Q416	QA404D	

REFERENCE DESIGNATIONS NOT USED					
C408					

8. JUMPERS CLIPPED DURING FINAL CALIBRATION IF NECESSARY.

164TT
169

163		1
160		1
MODEL	NEXT ASSEMBLY	QTY

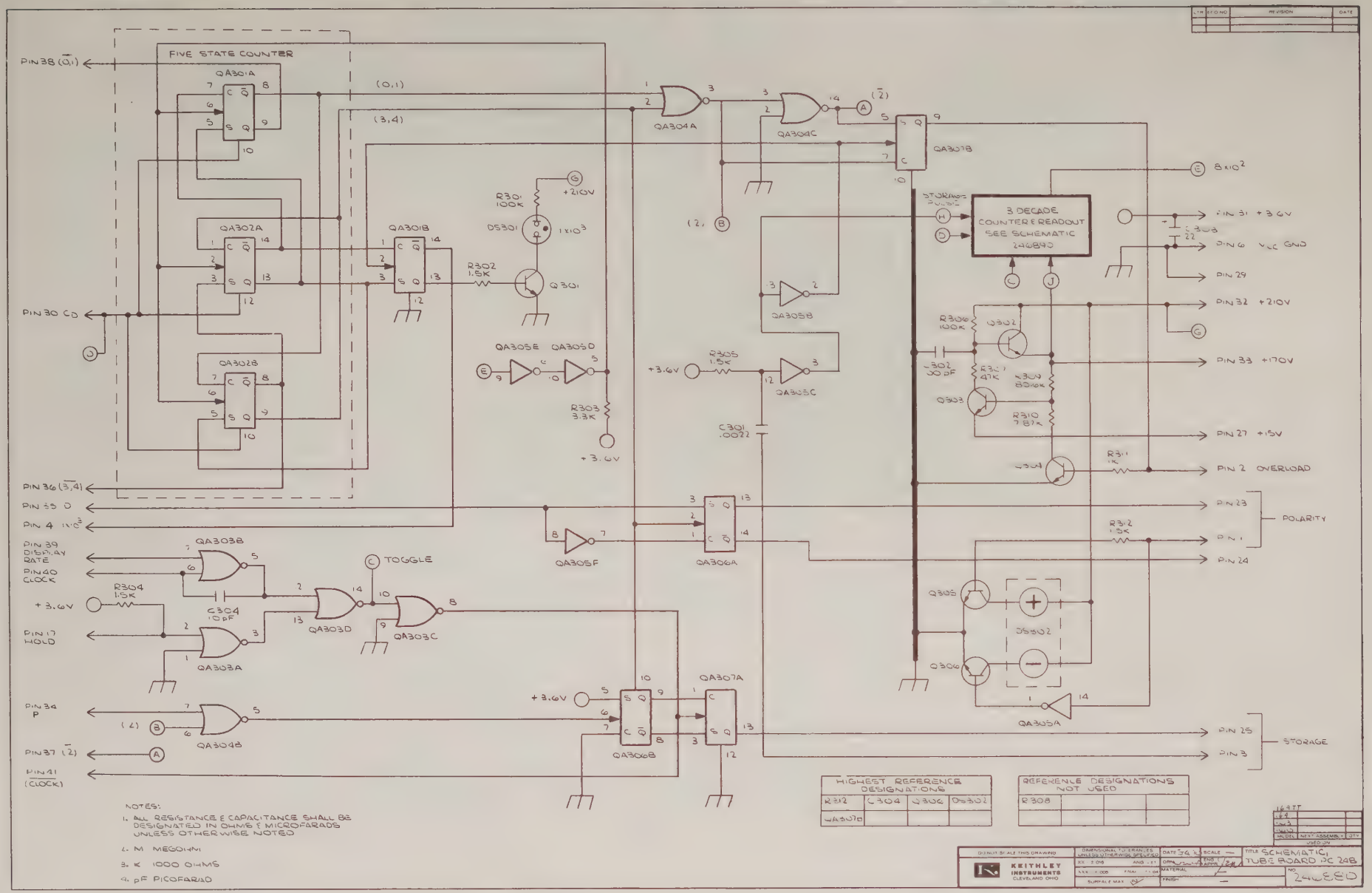
USED ON

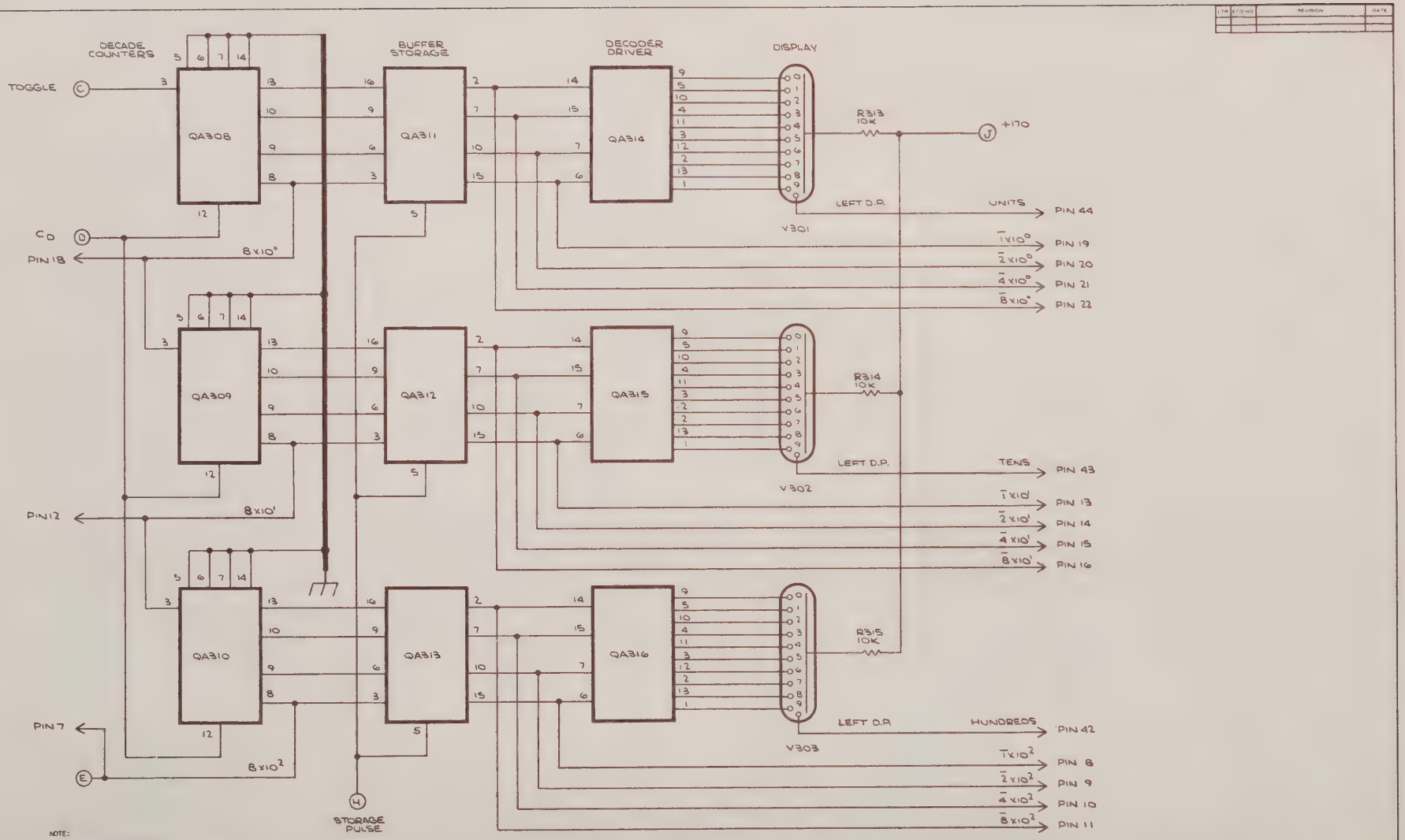
RMINED

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 3-21-70	SCALE —
KEITHLEY INSTRUMENTS CLEVELAND, OHIO	XX = ± .015 — ANG = ±1°	DRN GECHA	ENG APPR
	XXX = ± .005 — FRAC = ±1/64	MATERIAL —	
	SURFACE MAX 63	FINISH —	

TITLE SCHEMATIC, INTEGRATOR BOARD

NO 24690E


FIVE STATE COUNTER
QA301A
QA302A
QA301B
QA302B
PIN 38 (0,1)
PIN 30 CD
PIN 36 (3,4)
PIN 35 D
PIN 4 1X10³
PIN 39 DISPLAY RATE
PIN 40 CLOCK
PIN 17 HOLD
PIN 34 P
PIN 37 (2)
PIN 41 (CLOCK)
(0,1)
(3,4)
QA304A
QA304C
QA307B
R301 100K
+21.0V
DS301
1X10³
Q301
R302 1.5K
QA305E
QA305D
R303 3.3K
+3.6V
QA305B
R305 1.5K
QA305C
C301 .0022
3 DECADE COUNTER & READOUT SEE SCHEMATIC 246890
STORAGE PULSE
8X10²
PIN 31 +3.6V
PIN 6 VCC GND
PIN 29
PIN 32 +21.0V
R306 100K
Q302
C302 .00 pF
R307 47K
R308 80.6K
Q303
R310 7.87K
PIN 33 +17.0V
PIN 27 +15V
R311 1K
Q304
PIN 2 OVERLOAD
QA305F
QA306A
R312 1.5K
PIN 23
PIN 1
PIN 24
POLARITY
QA303B
R304 1.5K
C304 10 pF
TOGGLE
QA303D
QA303C
QA303A
Q305
DS302
Q306
QA305A
QA304B
QA306B
QA307A
PIN 25
PIN 3
STORAGE
NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED
2. M MEGOHM
3. K 1000 OHMS
4. pF PICOFARAD
HIGHEST REFERENCE DESIGNATIONS
R312 C304 Q306 DS302
QA307B
REFERENCE DESIGNATIONS NOT USED
R308
KEITHLEY INSTRUMENTS CLEVELAND OHIO
TITLE SCHEMATIC, TUBE BOARD PC 248
246890



NOTE:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. K 1000 OHMS

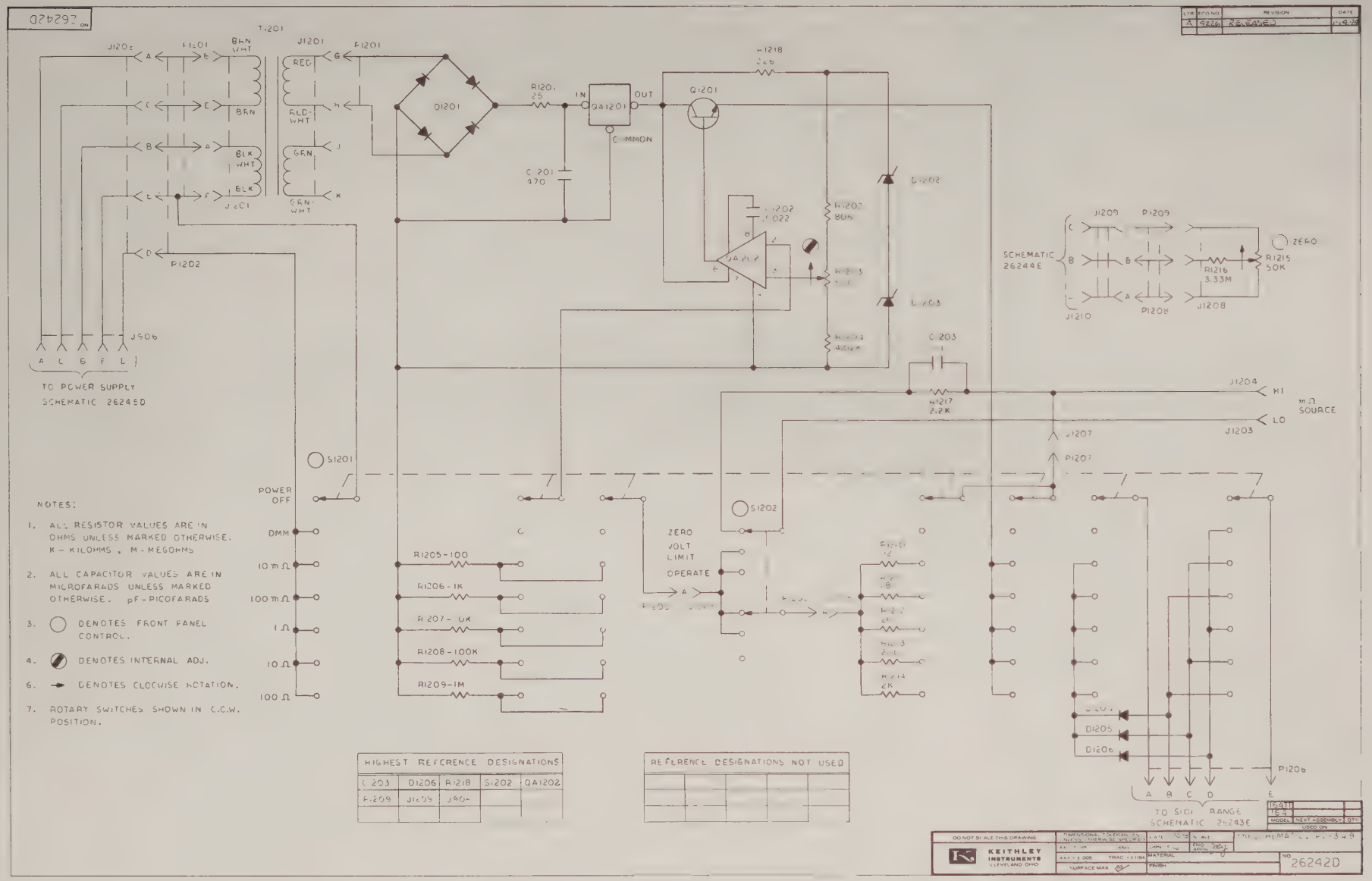
HIGHEST REFERENCE DESIGNATION					
R315	QA316	V303			

REFERENCE DESIGNATIONS NOT USED					

KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE SCHEMATIC, TUBE BOARD PC 248

NO 24689D



NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. K - KILOHMS, M - MEGOHMS
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. pF - PICOFARADS
3. ○ DENOTES FRONT PANEL CONTROL.
4. ◐ DENOTES INTERNAL ADJ.
6. → DENOTES CLOCWISE ROTATION.
7. ROTARY SWITCHES SHOWN IN C.C.W. POSITION.

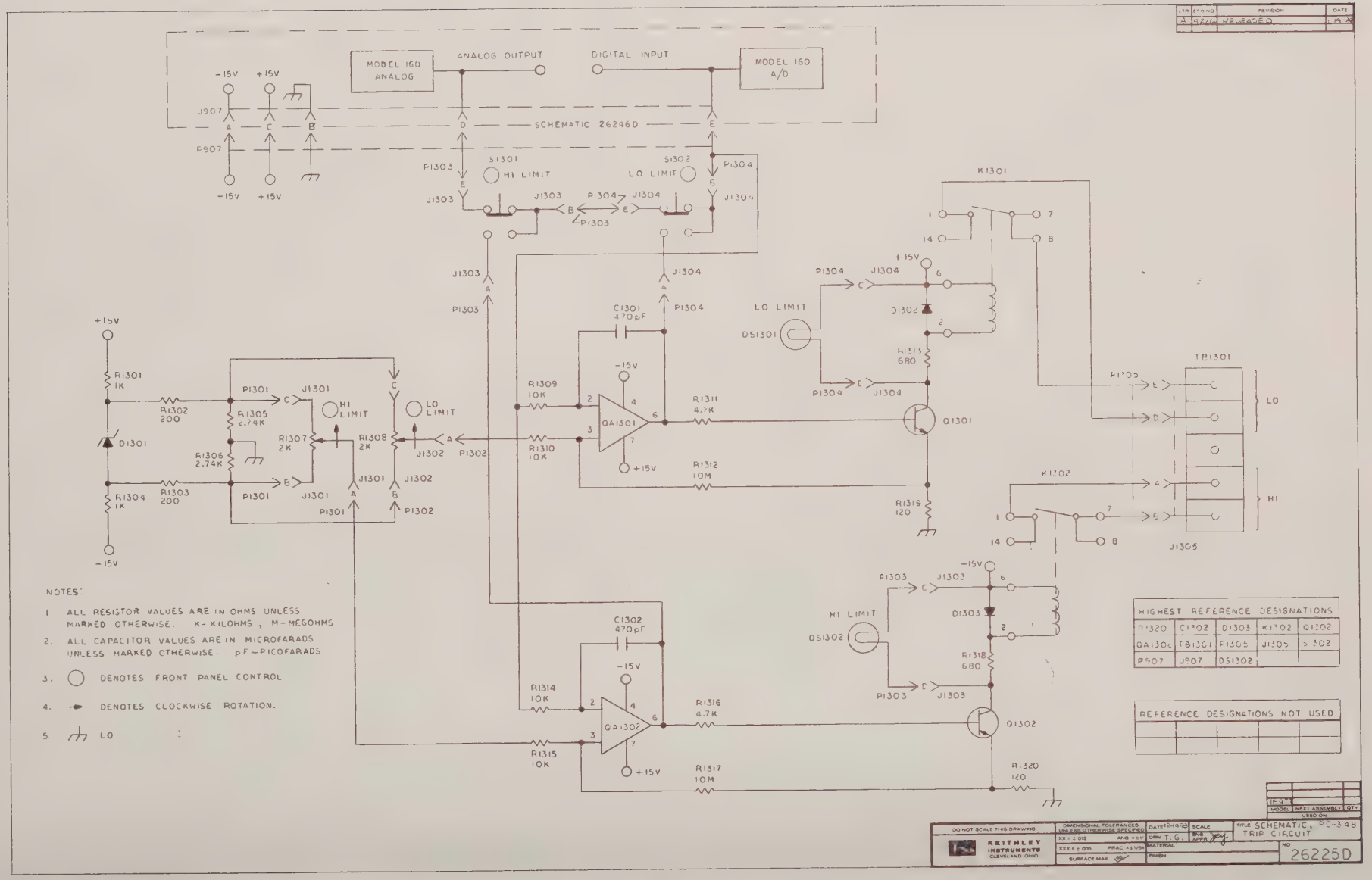
HIGHEST REFERENCE DESIGNATIONS				
C 203	D1206	R1218	S1202	QA1202
P1209	J1209	J90-		

REFERENCE DESIGNATIONS NOT USED				

LTR	ECO NO.	REVISION	DATE
A	9226	RELEASED	11-9-76

KEITHLEY INSTRUMENTS CLEVELAND OHIO

NO 26242D



NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. K-KILOHMS, M-MEGOHMS
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. pF-PICOFARADS
3. ○ DENOTES FRONT PANEL CONTROL
4. → DENOTES CLOCKWISE ROTATION.
5. ⏚ LO

LTR	ECO NO	REVISION	DATE
A	9226	RELEASED	4-29-75

HIGHEST REFERENCE DESIGNATIONS

P1320	C1302	D1303	K1302	Q1302
QA1304	TB1301	F1305	J1305	S1302
P907	J907	DS1302		

REFERENCE DESIGNATIONS NOT USED

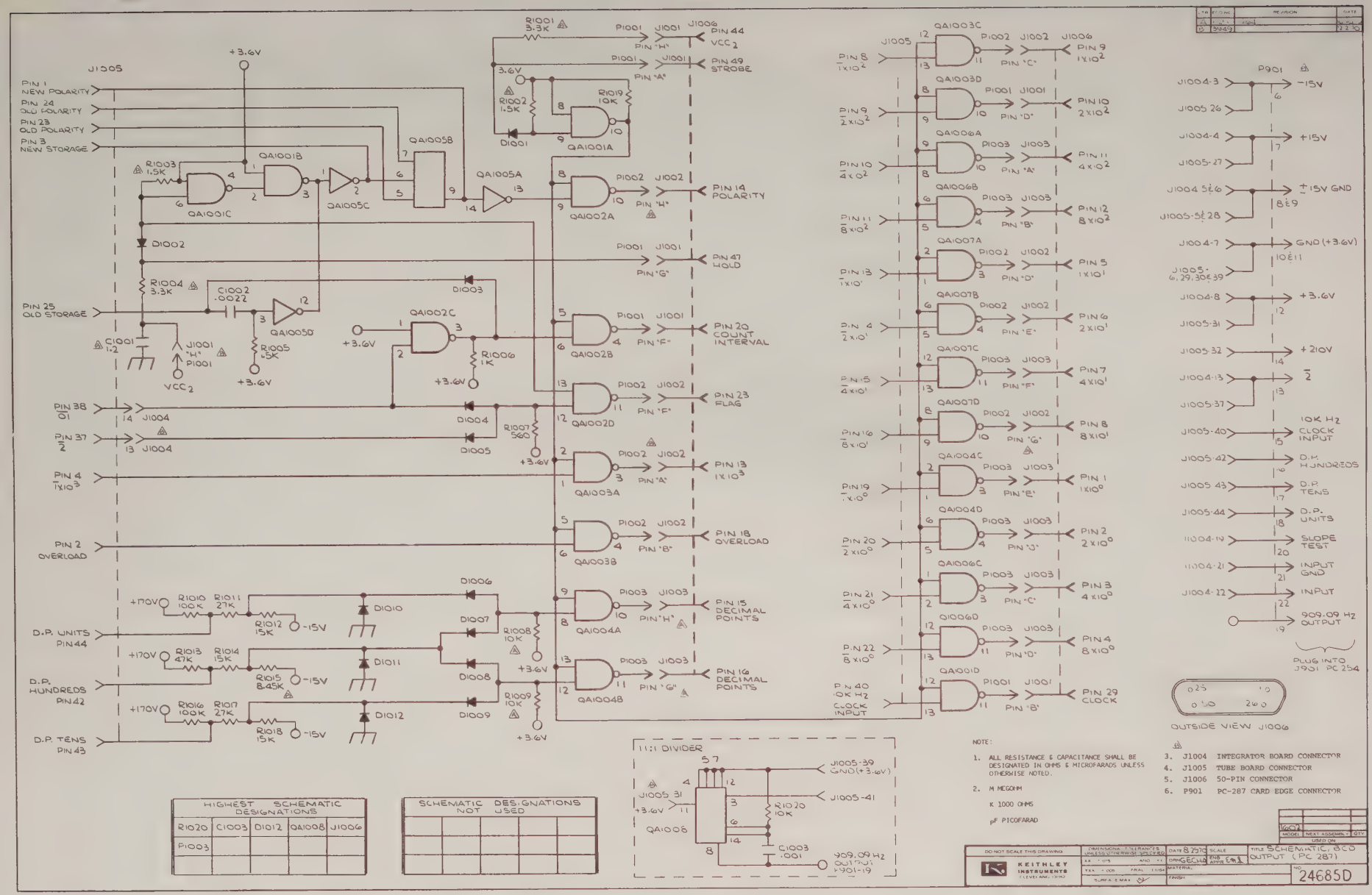
16-211			
MODEL	NEXT ASSEMBLY	QTY	USED ON

DO NOT SCALE THIS DRAWING — DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX ± .015, ANG ± 1°, XXX ± .005, FRAC ± 1/64, SURFACE MAX — DATE 12-10-73 — SCALE EVS — DRN T.G. — MATERIAL — FINISH

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

TITLE SCHEMATIC, PC-348 TRIP CIRCUIT

NO 26225D



HIGHEST SCHEMATIC DESIGNATIONS				
R1020	C1003	D1012	QA1008	J1006
P1003				

SCHEMATIC DESIGNATIONS NOT USED				

NOTE:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. M MEGOHM
   K 1000 OHMS
   pF PICOFARAD
3. J1004 INTEGRATOR BOARD CONNECTOR
4. J1005 TUBE BOARD CONNECTOR
5. J1006 50-PIN CONNECTOR
6. P901 PC-287 CARD EDGE CONNECTOR

REVISION	DATE
D 3949	2 2 80

MODEL	NEXT ASSEMBLY	QTY
1601		

USED ON

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS (CLEVELAND, OHIO)

DIMENSIONS, TOLERANCES UNLESS OTHERWISE SPECIFIED

DRAWN GEC 1-4 | ENG APPR | MFG APPR

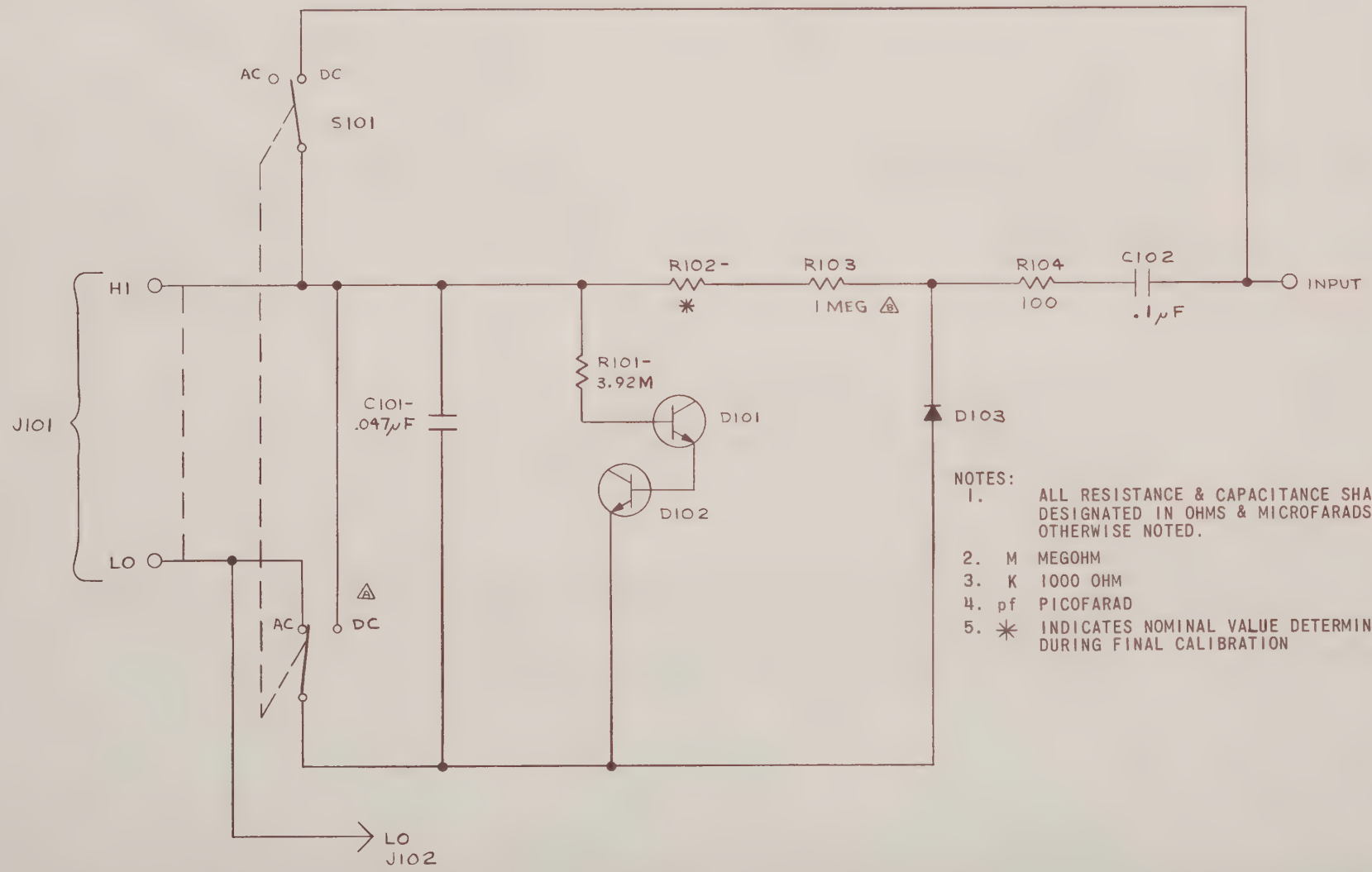
DATE 8 2 80 | SCALE | MATERIAL | FINISH

TITLE SCHEMATIC, BCD OUTPUT (PC 287)

NO 24685D

24669C

LTR	ECO NO	REVISION	DATE
A	PIM 223	ADDED RULE TO S101	5-25-70
B	PIM 281	CHG R103-933K TO A-03-1MEG	10-1-70



NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. M MEGOHM
3. K 1000 OHM
4. pf PICOFARAD
5. * INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION

REFERENCE DESIGNATIONS NOT USED				

HIGHEST REFERENCE DESIGNATION				
J102	S101	C102	R104	D103

1601		1
MODEL	NEXT ASSEMBLY	QTY
USED ON		

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED
XX ± .016 ANG ± 1°
XXX ± .005 FRAC ± 1/64
SURFACE MAX 63

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DATE 5-11-70 SCALE —
DRN RGJ ENG APPR
MATERIAL —
FINISH —

TITLE SCHEMATIC, AC-DC PROBE

NO. 6690

KEITHLEY INSTRUMENTS, INC.
28775 AURORA ROAD
CLEVELAND, OHIO 44139

SERVICE FORM

MODEL NO._____ SERIAL NO._____ P.O. NO._____ DATE_____ R-

NAME _____ PHONE _____

COMPANY _____

ADDRESS _____ CITY _____ STATE _____ ZIP_____

1. Describe problem and symptoms using quantitative data whenever possible (enclose readings, chart recordings, etc.) _____

_____

_____ (Attach additional sheets as necessary).

2. Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

3. List the positions of all controls and switches on both front and rear panels of the instrument. _____

_____

4. Describe input signal source levels, frequencies, etc. _____

_____

_____

5. List and describe all cables used in the experiment (length, shielding, etc.).

_____

_____

6. List and describe all other equipment used in the experiment. Give control settings for each. _____

_____

_____

7. Environment:
   Where is the measurement being performed? (Factory, controlled laboratory, out-of-doors, etc.) _____
   What power line voltage is used? _____ Variation? _____ Frequency? _____
   Ambient temperature? _____°F. Variation? _____°F. Rel. Humidity? _____
   Other _____

8. Additional Information. (If special modifications have been made by the user, please describe below.) _____

_____

_____ REV 0774

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KEITHLEY

Keithley Instruments, Inc./28775 Aurora Road/Cleveland, Ohio 44139/(216) 248-0400/Telex: 98-5469

Keithley Instruments GmbH/Heiglhofstrasse 5/D-8000 Munchen 70/(089) 714-40-65/Telex: 521 21 60

Keithley Instruments, Ltd./1, Boulton Road/GB-Reading, Berkshire RG2 ONL/(0734) 86 12 87

Keithley Instruments SARL/44, Rue Anatole France/F-91121 Palaiseau Cedex/01-014-22-06/Telex: (842) 204188